Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

MAY 1953 PRICE 2/6

627

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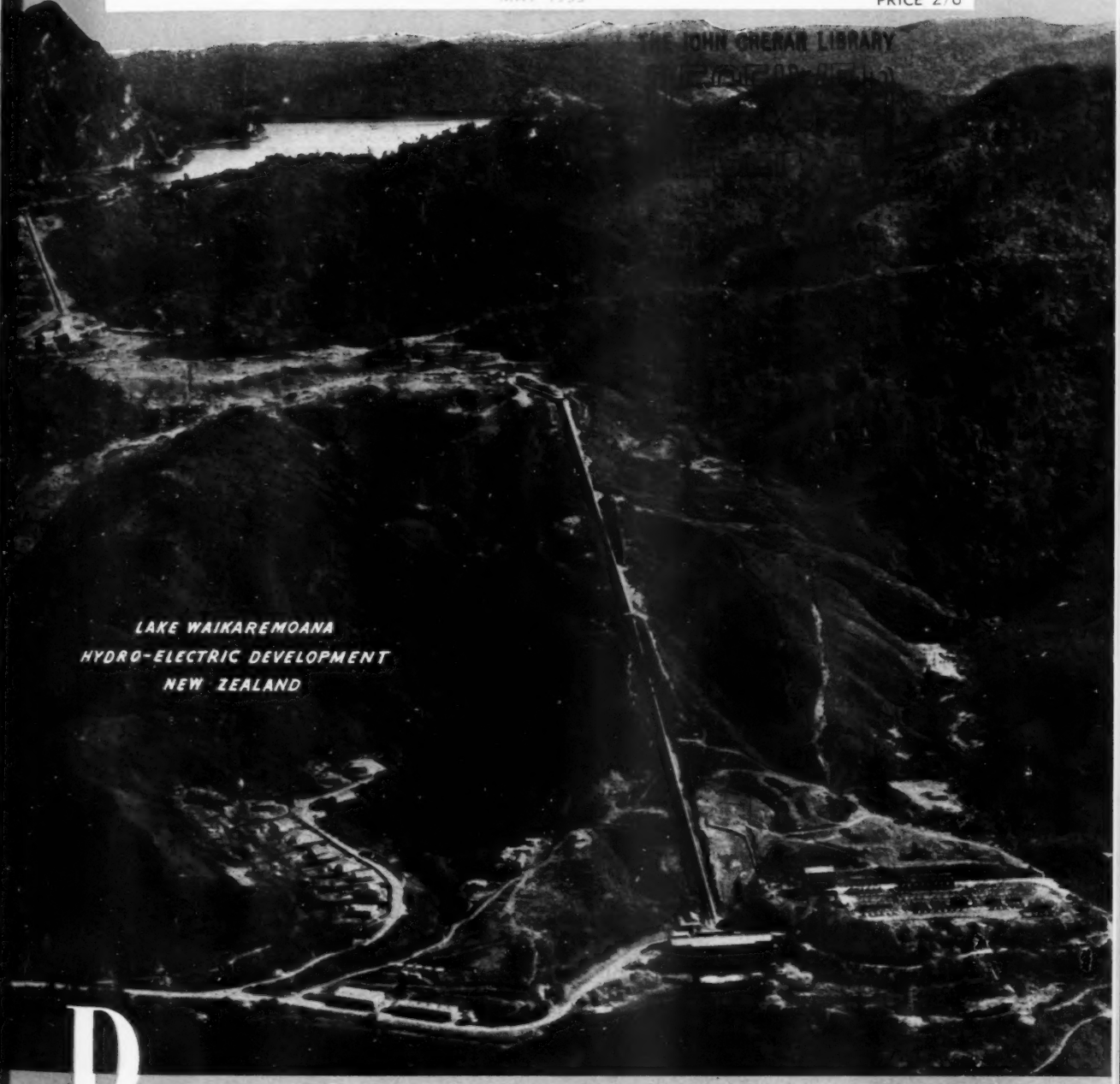


LAKE WAIKAREMOANA
HYDRO-ELECTRIC DEVELOPMENT
NEW ZEALAND

Boving

The upper station - Kaitawa - has two 21,000 BHP Boving Francis Turbines; the lower station - Tuai - one Boving Francis Turbine of 28,000 BHP.

& COMPANY LIMITED WATER POWER ENGINEERS

LONDON : AUSTRALIA : NEW ZEALAND : INDIA : PAKISTAN

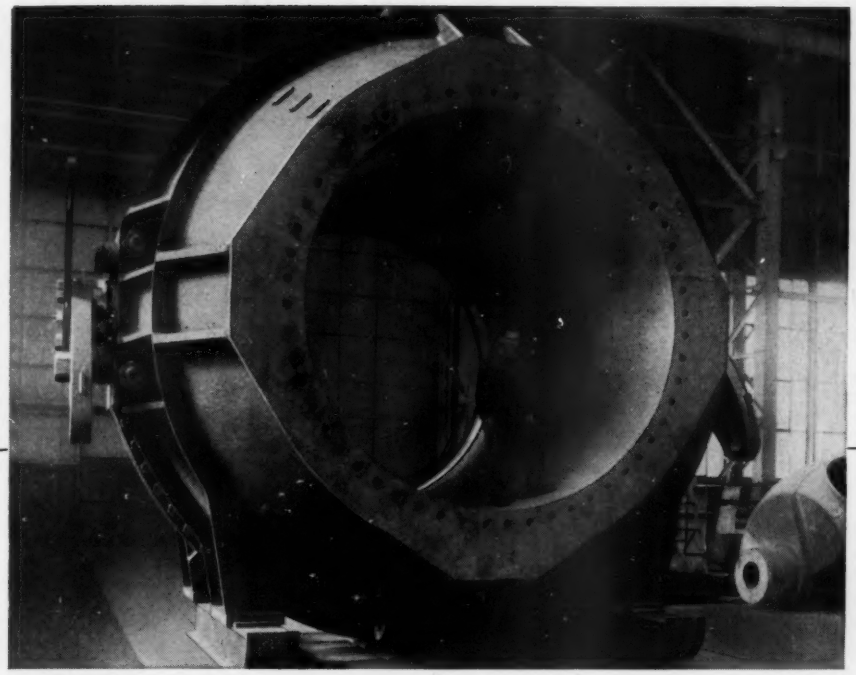
Lasting Craftsmanship

Final stages of preparation
prior to shipment of
66-kV small-oil-volume circuit-
breakers

Reyrolle

A. REYROLLE & COMPANY LIMITED, HEBBURN · CO. DURHAM.

160 ton Straightflow Valve



'ENGLISH ELECTRIC' have recently delivered three 11 ft. bore straightflow valves — probably the largest smooth-bore valves in the world — and are making two more. These valves work under a head of 322 ft. and the overall diameter is 20 ft. Operation is by external servo-motors. Each valve serves as an inlet valve for a 74,000 h.p. 'ENGLISH ELECTRIC' water turbine.

'ENGLISH ELECTRIC' straightflow valves are manufactured for all diameters and heads, and their robust spherical form makes them particularly suitable for high pressures. Their principle of operation eliminates water-hammer, wear and backlash, side thrust and vibration. They are positive and safe; no deviation of water stream can take place when they are being opened or closed.

'ENGLISH ELECTRIC'

water power

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

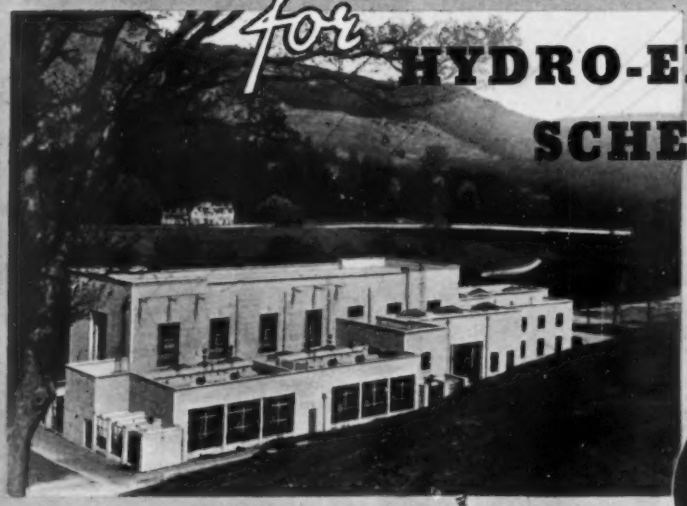
Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

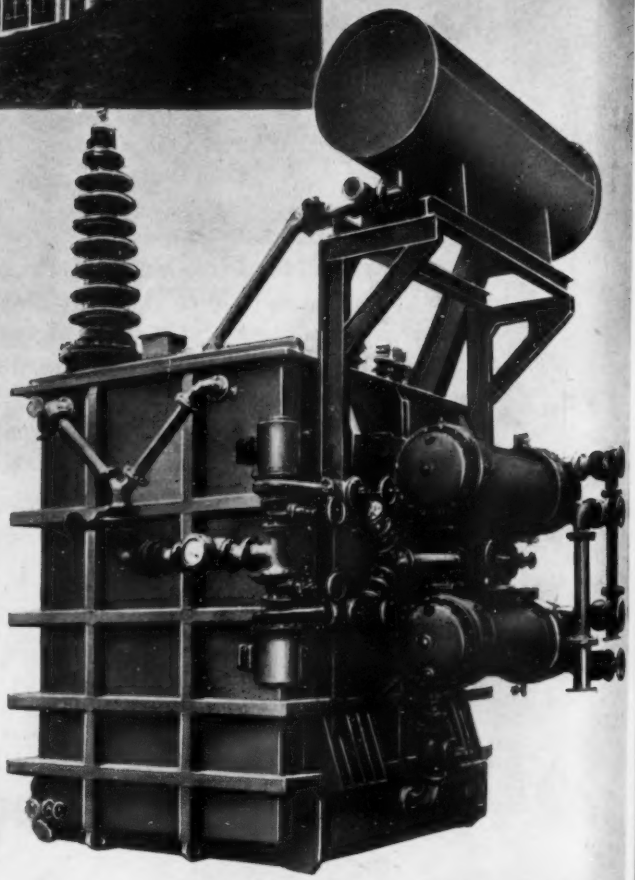
PEEBLES

power transformers

for HYDRO-ELECTRIC SCHEMES



CLUNIE POWER STATION of the North of Scotland Hydro-Electric Board where 6-20,000 K.V.A. water-cooled transformers, as illustrated at right, operate in two 60,000 K.V.A. 11,000/132,000-volt three-phase banks. Also installed at this power station is a three-phase magnetically shielded reactor capable of dealing with a power fault of 400,000 K.V.A. at 11,000 volts.



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EDINBURGH, SCOTLAND

LONDON OFFICE: 4 CARLOS PLACE, LONDON, W.1

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INTERNATIONAL ENGINEERING COMPANY, INC.
MORRISON-KNUDSEN COMPANY, INC.

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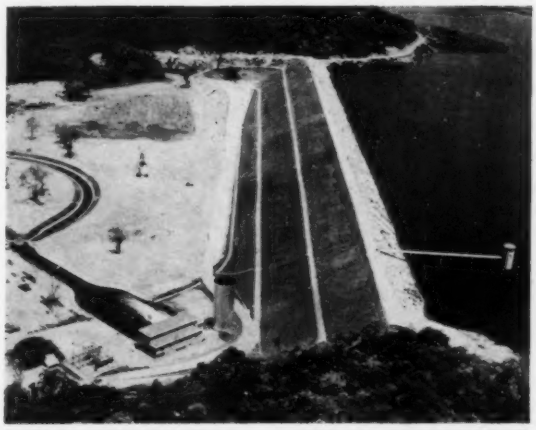

International Engineering Company and Morrison-Knudsen combine the varied skills, manpower and world-wide experience needed for the design and construction of large-scale flood control and hydro-electric schemes.

Four of our recent projects are shown here. The teamwork that built these dams is at your disposal for projects anywhere in the free world.

1 GAL OYA DAM, Ceylon. Completed 1952 for flood control, irrigation, hydroelectric power. 3400 ft. long; 125 ft. high.

2 KAJAKAI DAM, Kingdom of Afghanistan. Completion scheduled for March, 1953. 885 ft. long; 300 ft. high. Kajakai is a key project in Afghanistan national development plan.

3 ARGHANDAB DAM, Kingdom of Afghanistan. Completed in 1952. 1804 ft. long; 167 ft. high. Arghandab is another step in the Kingdom's long-range development program.

4 KENNEY DAM, British Columbia.* Completed November, 1952. 1600 ft. long; 295 ft. high. Kenney Dam is a unit in the Nechako-Kitimat project being built for the Aluminum Company of Canada.

*Design only.

For complete information write:

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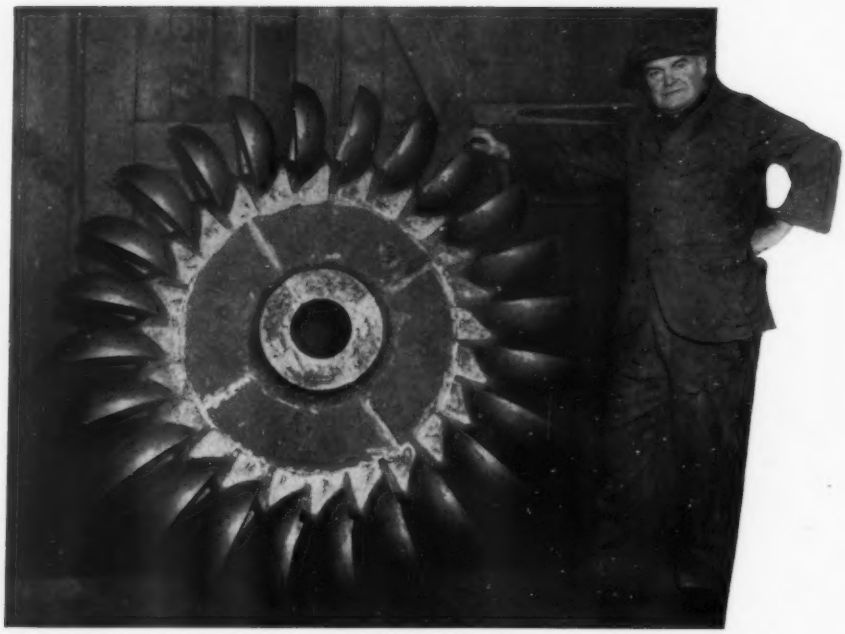

Aluminium Bronze Runner Casting supplied to Messrs. Gilbert Gilkes & Gordon Ltd., Kendal, for a 750 H.P. Pelton Wheel. This is for one of two similar turbines which will be installed at the Kilembe Copper Mines, Uganda.

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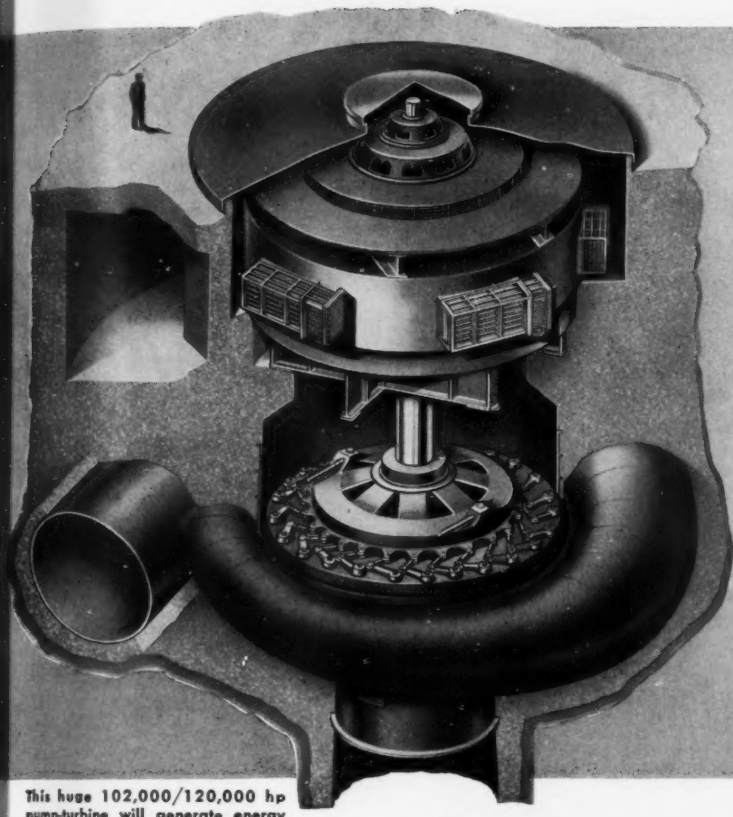
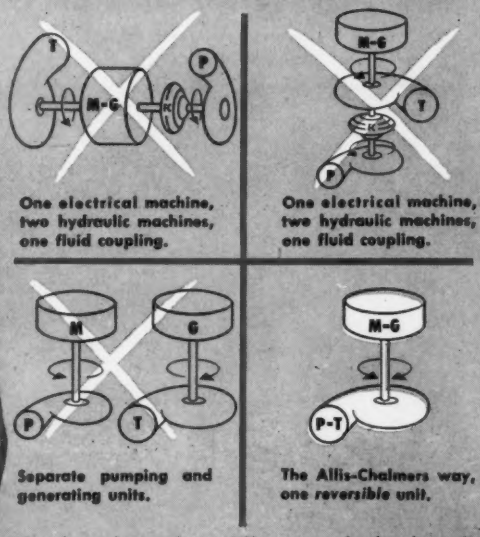
B.155

ALLIS-CHALMERS Pioneers *REVERSIBLE* Pump-Turbines!



This huge 102,000/120,000 hp pump-turbine will generate energy during peak demand periods, then reverse and — using surplus power from other plants — restore water to the reservoir during off-peak periods. Power value differential will make operation economical.

HOW REVERSIBLE PUMP-TURBINE REDUCES EQUIPMENT NEED



Sketches above show different methods of applying motive and generating equipment for pumped storage. Note that the Allis-Chalmers reversible pump-turbine at lower right requires least equipment and simplest power plant construction.

NOW BUILDING 5 UNITS FOR PUMPED STORAGE

THIS RECORD SIZE pump-turbine is now under construction by Allis-Chalmers for the Hiwassee dam in North Carolina. It combines in one reversible, two-element unit an electrical machine rated 102,000 hp as the world's largest motor and a hydraulic machine with the world's largest Francis runner.

When operating at maximum head as a turbine, this reversible unit will develop 120,000 hp. As a pump, it will move a maximum of 5200 cfs, 3.3 billion gallons per day . . . three times the capacity of the largest existing pump.

Allis-Chalmers — builder of over 12 millions of installed hydraulic horsepower — pioneered the development of the reversible pump-turbine for pumped storage. A-C offers you undivided responsibility, being able to design and build *all* elements of an entire reversible pump-turbine unit.

Of the five reversible pump-turbines A-C is now building, the Hiwassee unit is the largest. First scheduled for service is the 12,650 hp unit for the Flatiron Power & Pumping plant in Colorado. Three 19,000 hp units for the Sao Paulo Light & Power Co., Ltd., Brazil are now being built at Canadian Allis-Chalmers, Ltd., Montreal.

You get the real design advances *first* from Allis-Chalmers. And dealing with A-C is convenient, too, with 95 sales offices and 65 distributors located in 53 countries. For your free copies of Reversible Pump-Turbine Bulletin 01R7784 and illustrated, 56-page Bulletin 02B7301 of world famous hydro plants, just call your nearest A-C distributor or write to Allis-Chalmers, Milwaukee 1, Wisconsin, U.S.A. A-4011

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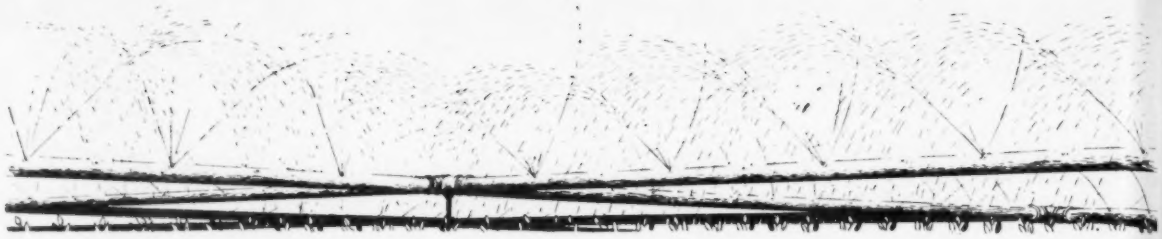

Building for the Industries of the World

WATER The Hunyani Poort Dam, Southern Rhodesia, recently constructed by Richard Costain Ltd., supplies water for Salisbury Urban and Municipal areas; for the development of the new township of Norton and for a 4,000 acre irrigation scheme.

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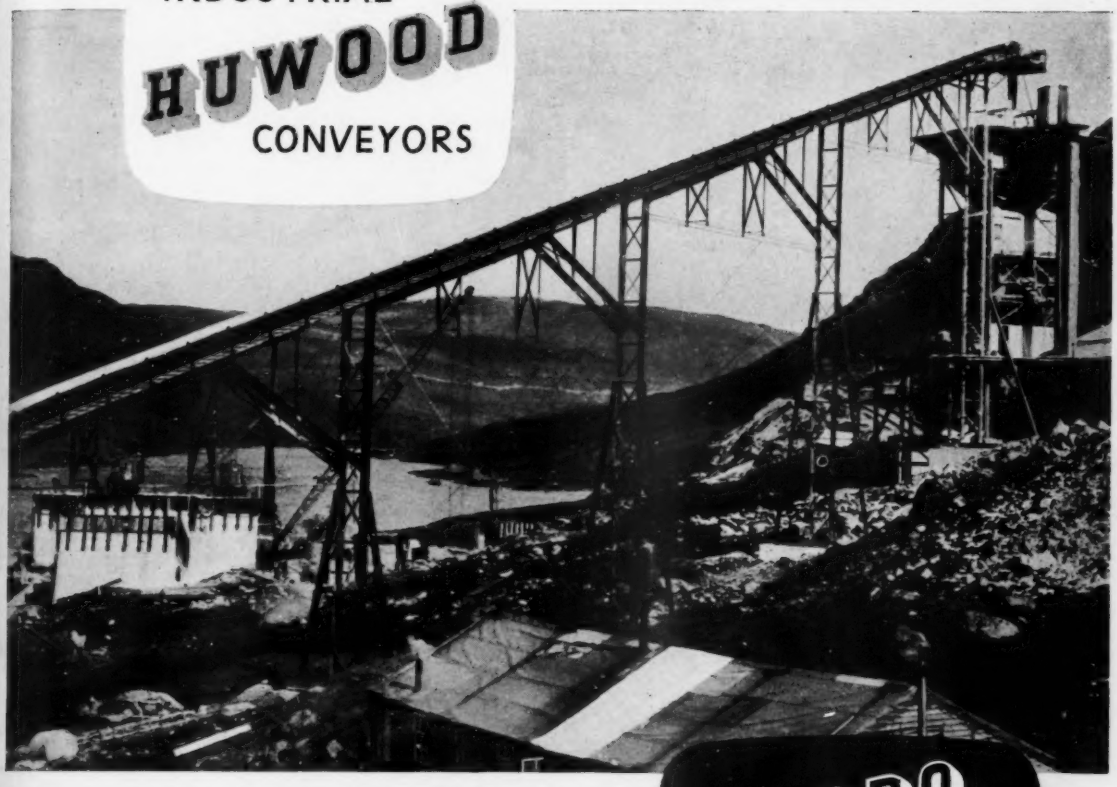

HYDRO ELECTRIC

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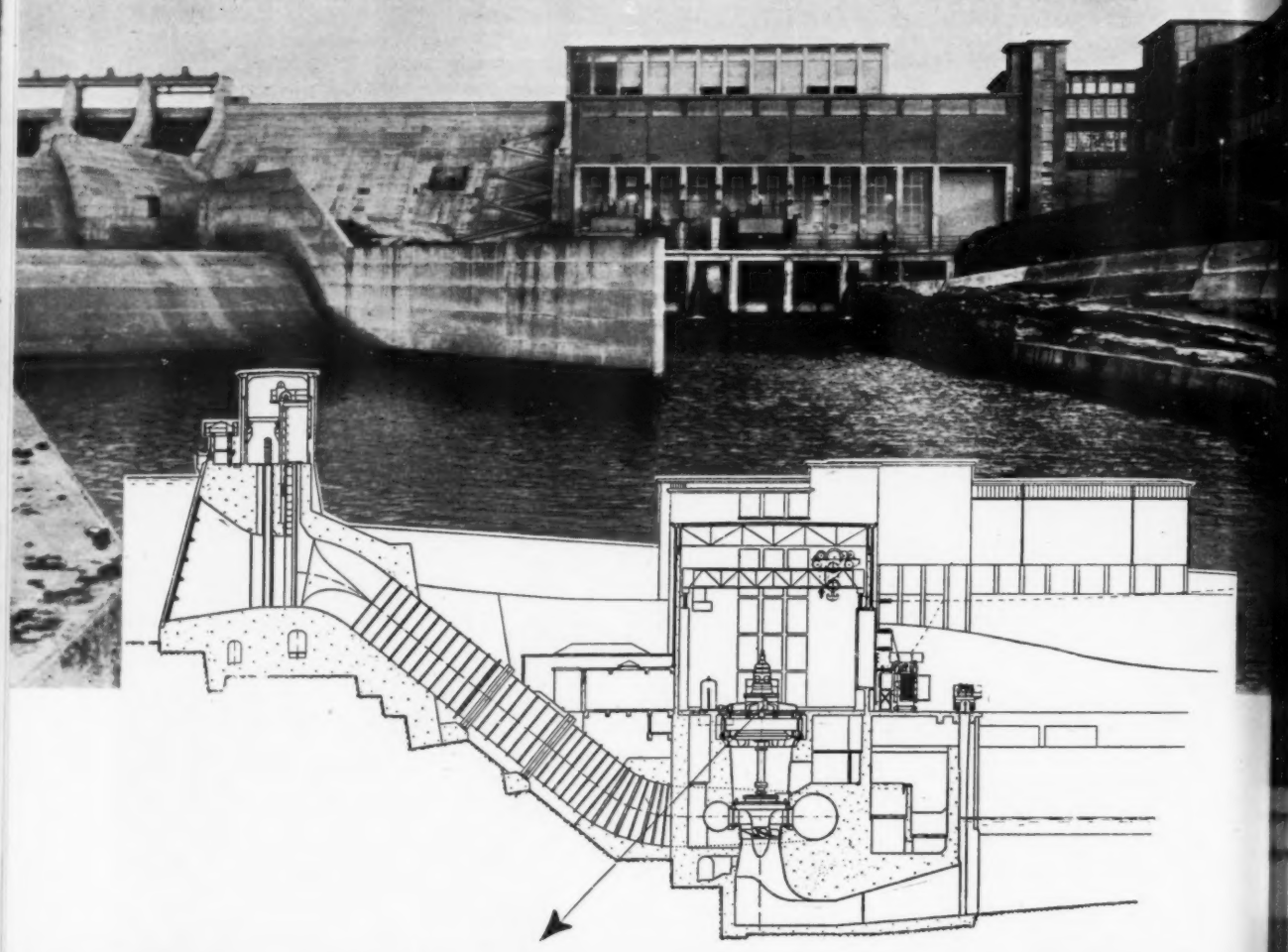

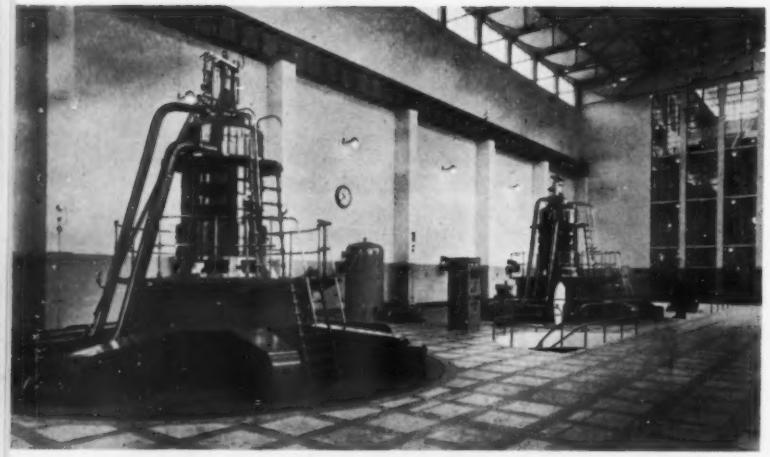

KMW

Two Kaplan turbines each developing 31,700 H.P. at 28·2 metres head and 187·5 r.p.m. One house turbine of 580 H.P.

Turbines and Governors delivered by

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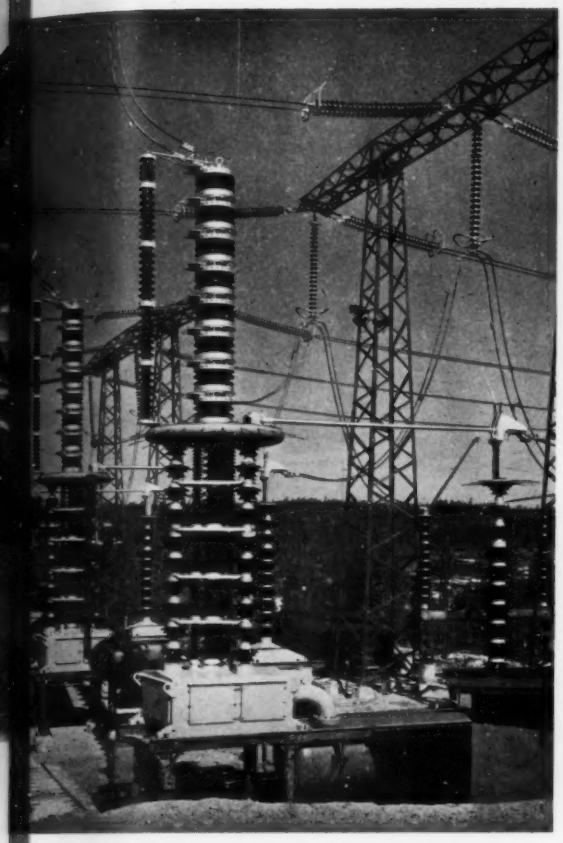
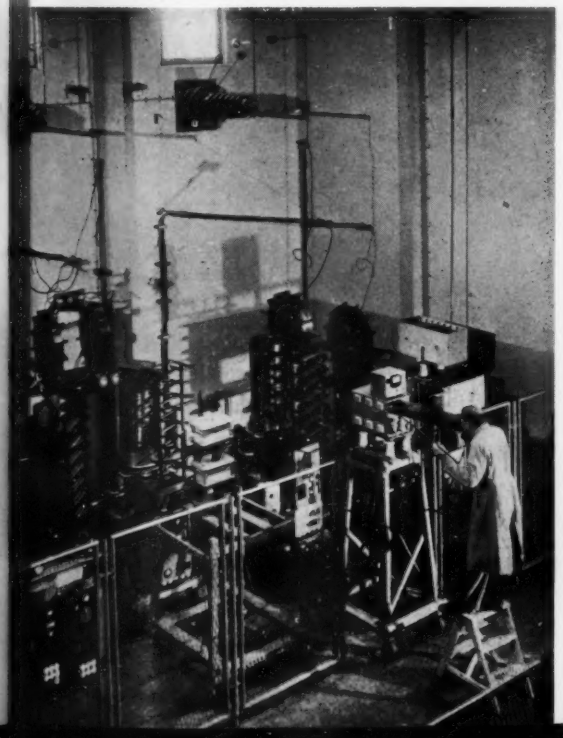
Progress in Power Transmission



ve: A 380 kV air-blast circuit breaker

w: Trial plant for research on high-voltage mercury arc valves



The past

During the seven decades of its existence ASEA have been responsible for pioneering work in many branches of electrical engineering. In 1890 Swedish and English patents were taken out for the three-phase system. The first three-phase generator, transformer and motor were completed and tested at the beginning of 1891, and in 1893 ASEA built a 9 mile long 9500 V three-phase transmission system capable of transmitting 100 h.p.

Today

The year 1952 marks one of the milestones in the history of power transmission, being the year in which the first 380 kV A.C. power line in the world was commissioned. Practically the entire electrical equipment required for the terminal stations of the line sections, which together form a 600 miles long power line capable of transmitting about half a million kVA, was supplied by ASEA, who also undertook a considerable portion of the scientific investigation and technical development work necessary to translate plans into facts.

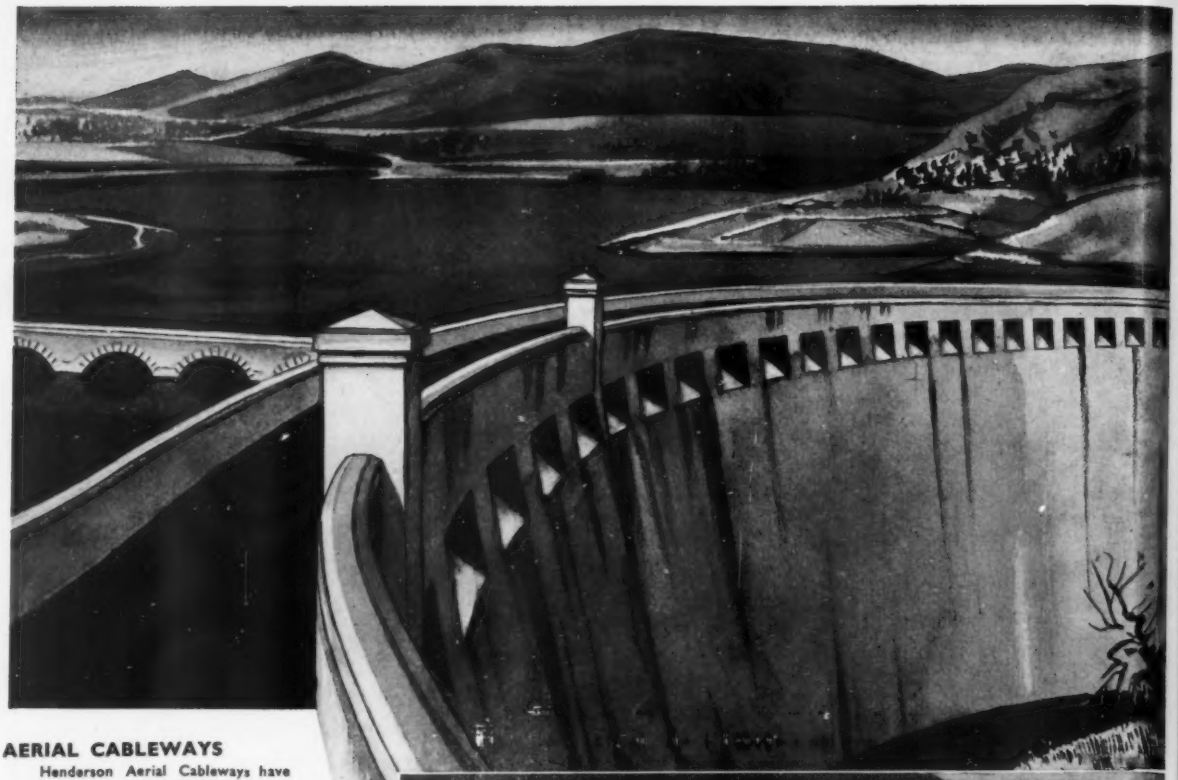
Looking ahead

The 380 kV system having proved highly satisfactory in every way, it is confidently anticipated that its use will be greatly extended in the future. There are certain power transmission problems, however, which can be solved more economically by the use of high tension D.C., such as submarine transmission and in some instances even cross country transmission. For a long time past ASEA have carried out an extensive research and development programme, two experimental plants have been in operation for a number of years and a commercial D.C. transmission project for Sweden is now in course of preparation. Painstaking pioneer work has given ASEA a leading position in high voltage power transmission and the firm has both the practical experience and the resources needed to tackle either type of high power transmission system.

For further details apply to

ASEA

VÄSTERÅS - SWEDEN



AERIAL CABLEWAYS

Henderson Aerial Cableways have solved the problem of raising, transporting and depositing concrete, shuttering and other materials for the construction of large Dams and Barrages.

Henderson Cableways are being used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

DERRICK CRANES

Henderson Cranes are chosen so often because of their speed and versatility in lifting materials. Their safety and economy in operation are also assured. Supplied to many leading contractors Henderson Derrick Cranes of all types and capacities can be manufactured for steam, electric, petrol or diesel drive. Cranes can also be fixed or travelling types. Normal sizes are from 10 cwt. to 60 tons Load capacity. With jibs up to 120 feet.

View of Henderson Cableways during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd

Henderson

Aerial Cableways

AND DERRICK CRANES

FOR HYDRO ELECTRIC SCHEMES

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Voith

Runners of Kaplan, Francis and Impulse Turbines as well as Storage Pumps supplied by us.

The Runner, the heart of the turbine, decides on the efficiency. By methodical research work we have for decades worked on the perfection of this essential part.

Illustrations:

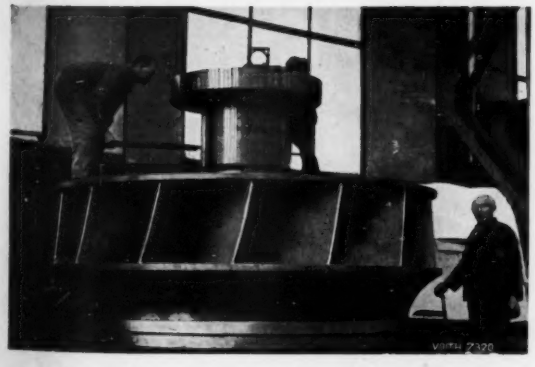
On the left: 34,600 H.P., Hirakud II (India)

Below: Runner 15 feet diameter, 115,500 H.P., Sungari (Manchuria)

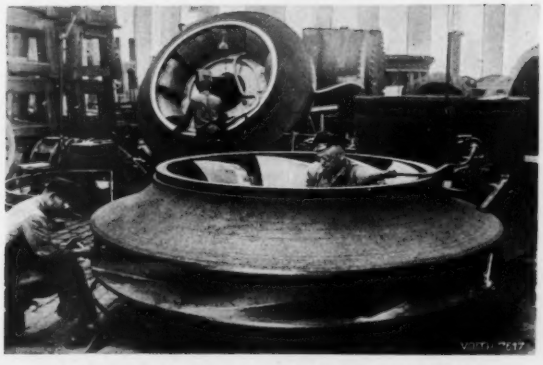
On the right: 52,400 H.P., Cipreses (Chile)

Below: Split runner 16′ 5″ diameter, 60,000 H.P., Parahyba (Brazil)

In the foreground: the runner model



Runner 60,000 H.P. output, Waldshut (Germany)



Storage Pump Impeller 24,100 H.P. input, Waldshut

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)

Telegrams: Voithwerk Heidenheimbrenz Germany (Württemberg)

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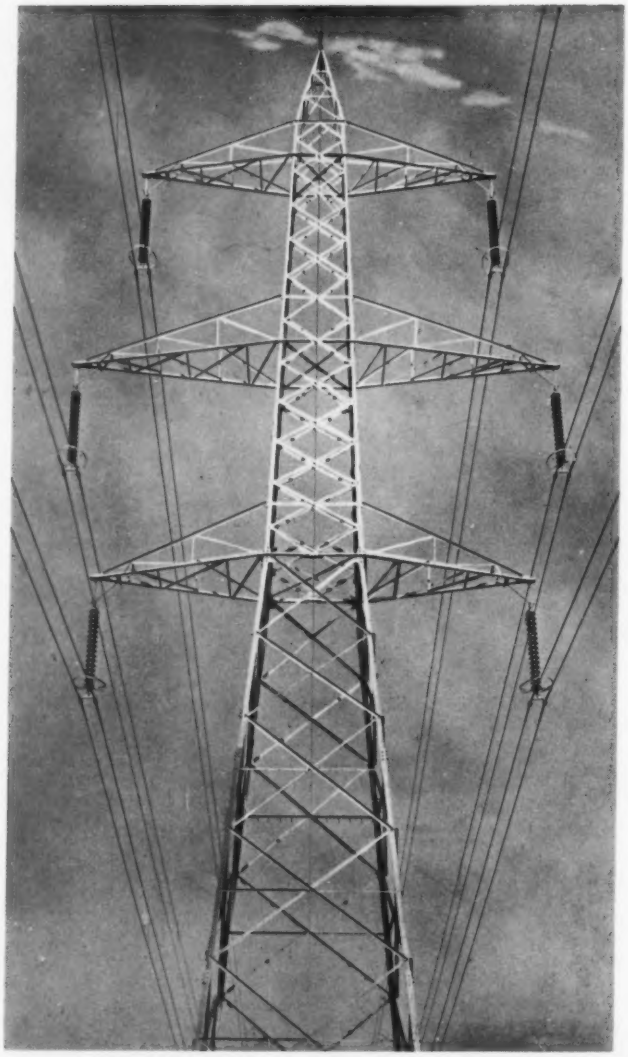

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This 230 kV transmission line, built to feed the new Iron and Steel Works at Cornigliano in Italy, is designed to carry six twin 300 sq. mm. (.257 sq. ins. C.E.) S.C.A. conductors across very rough country with ice loadings up to 8 kg/m (5,4 lb/ft).

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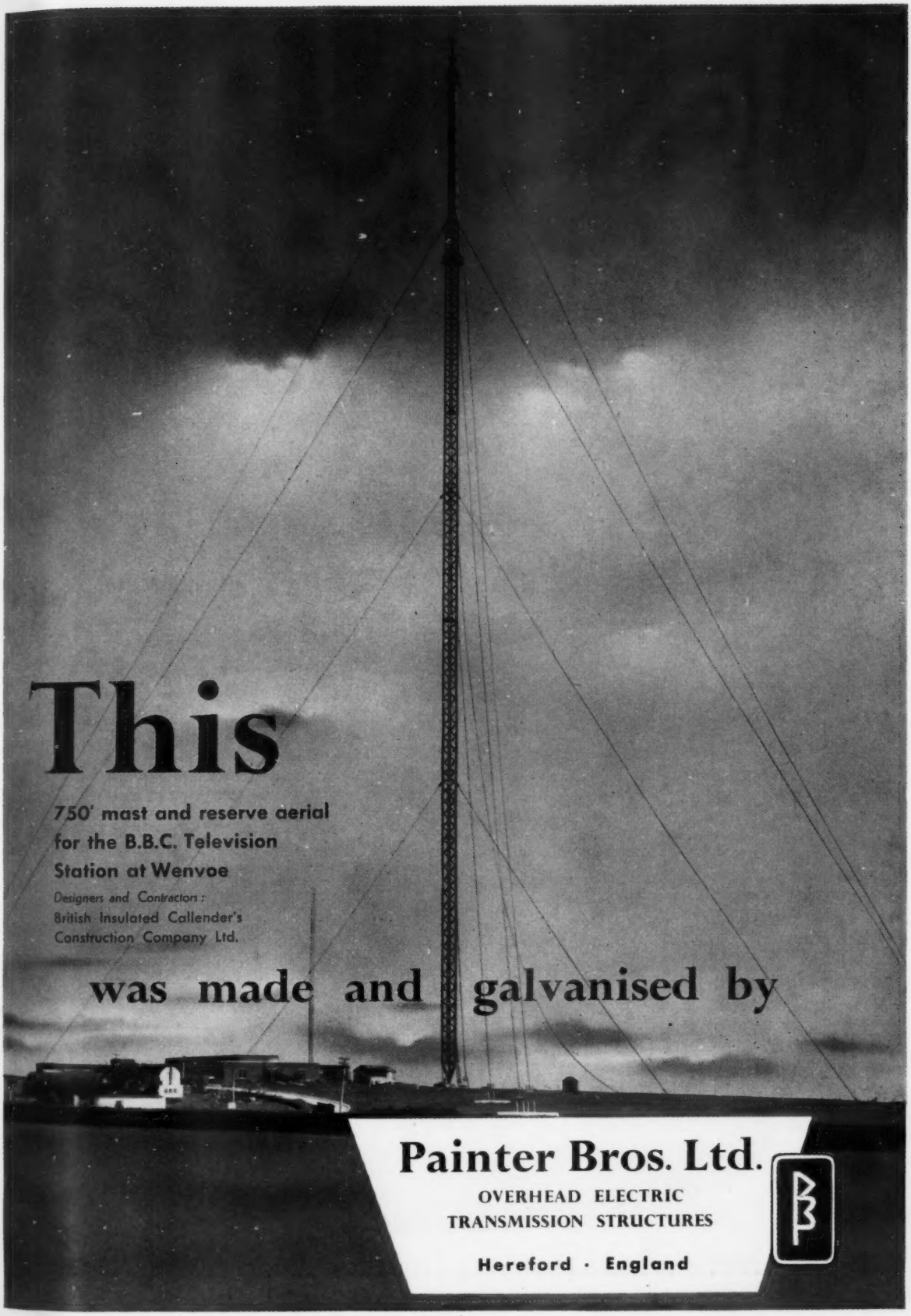
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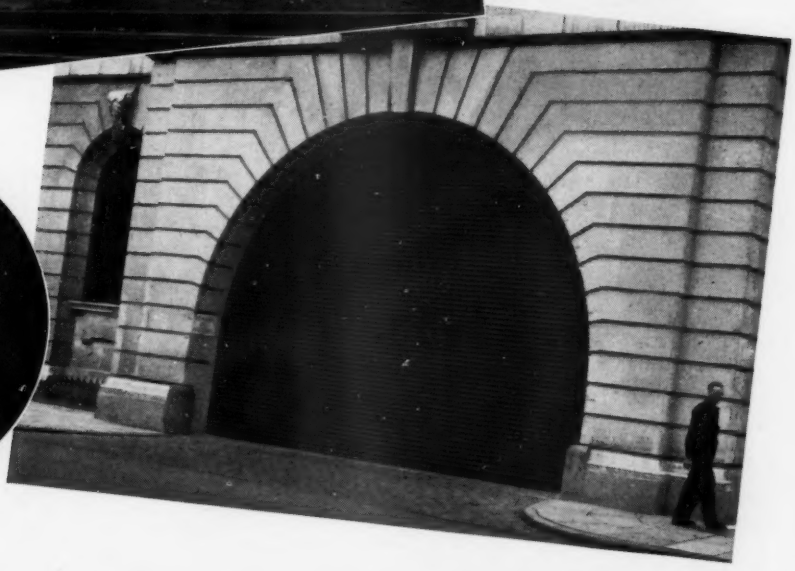

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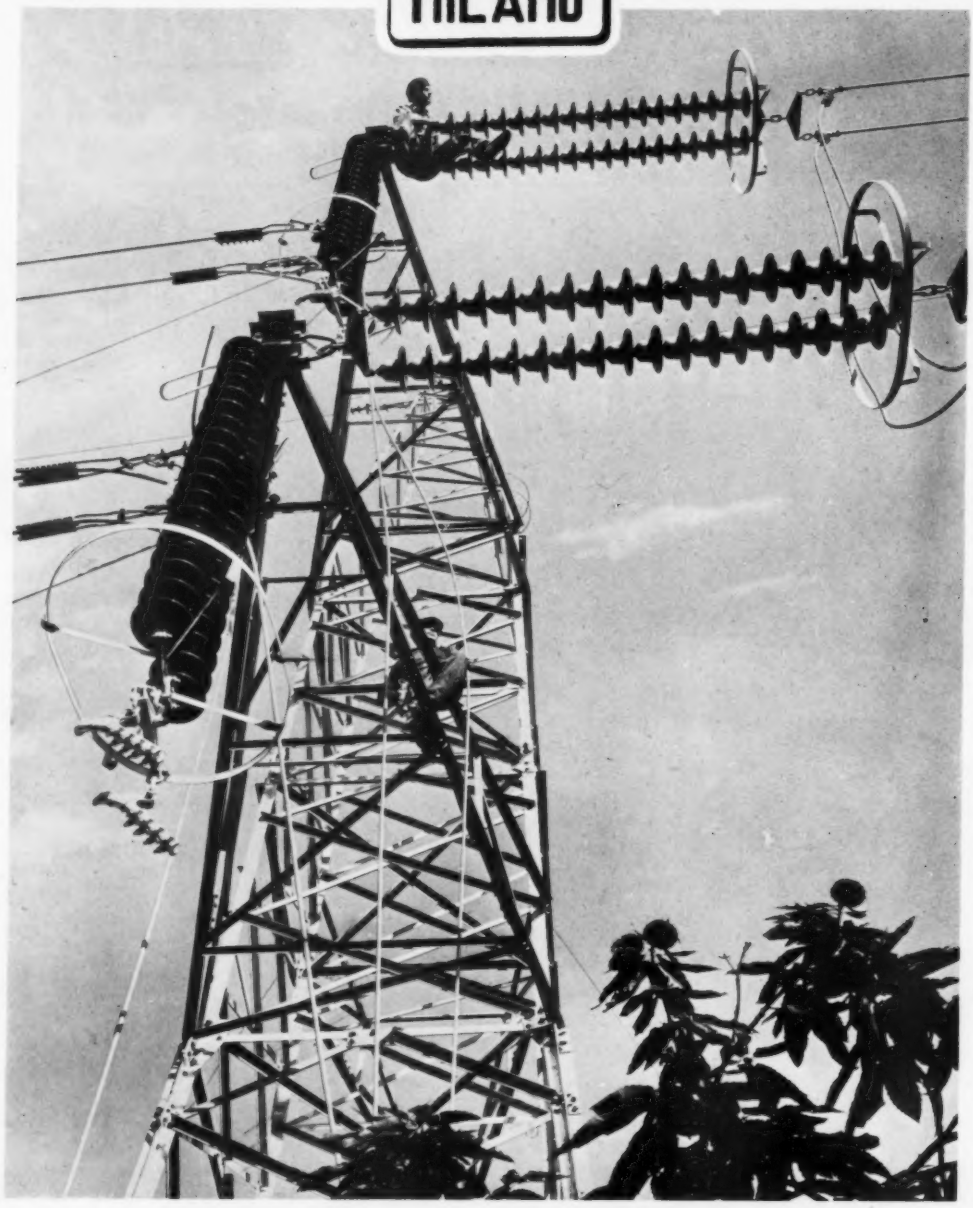

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For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. Suspension and Strain Clamps. Arcing Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

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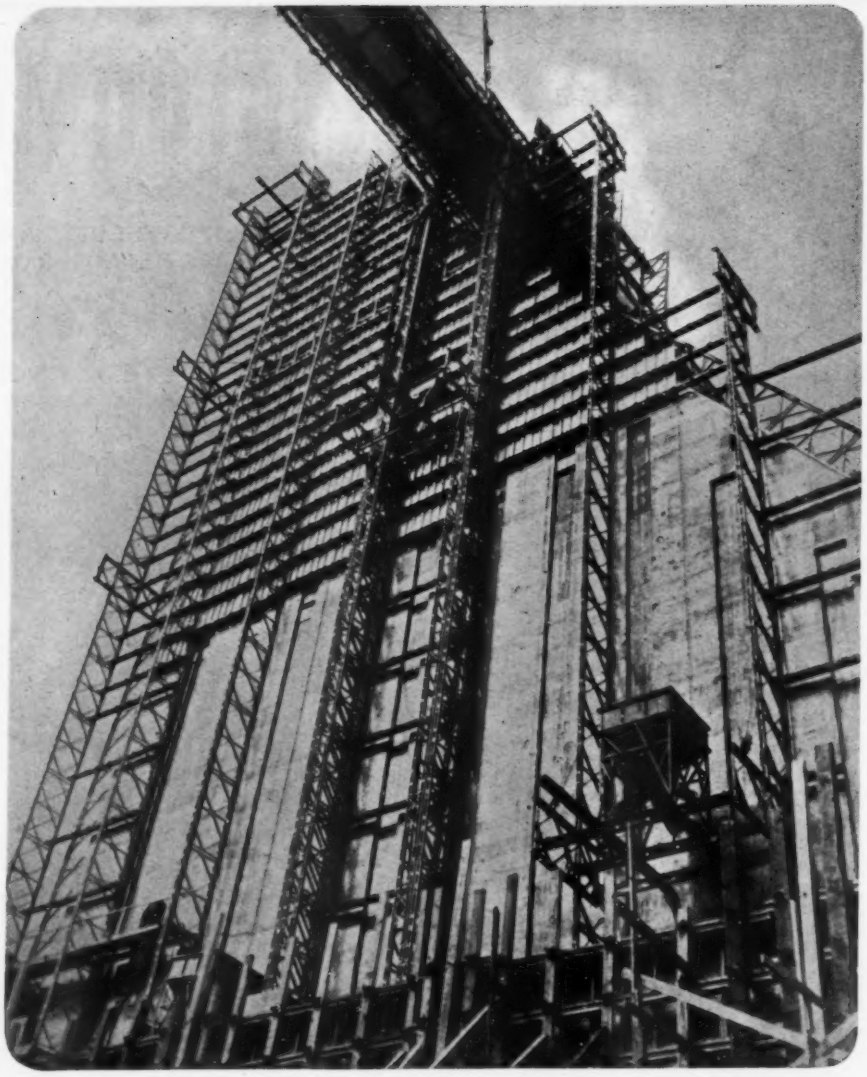

Photograph by courtesy of the Ontario Hydro Electric Commission

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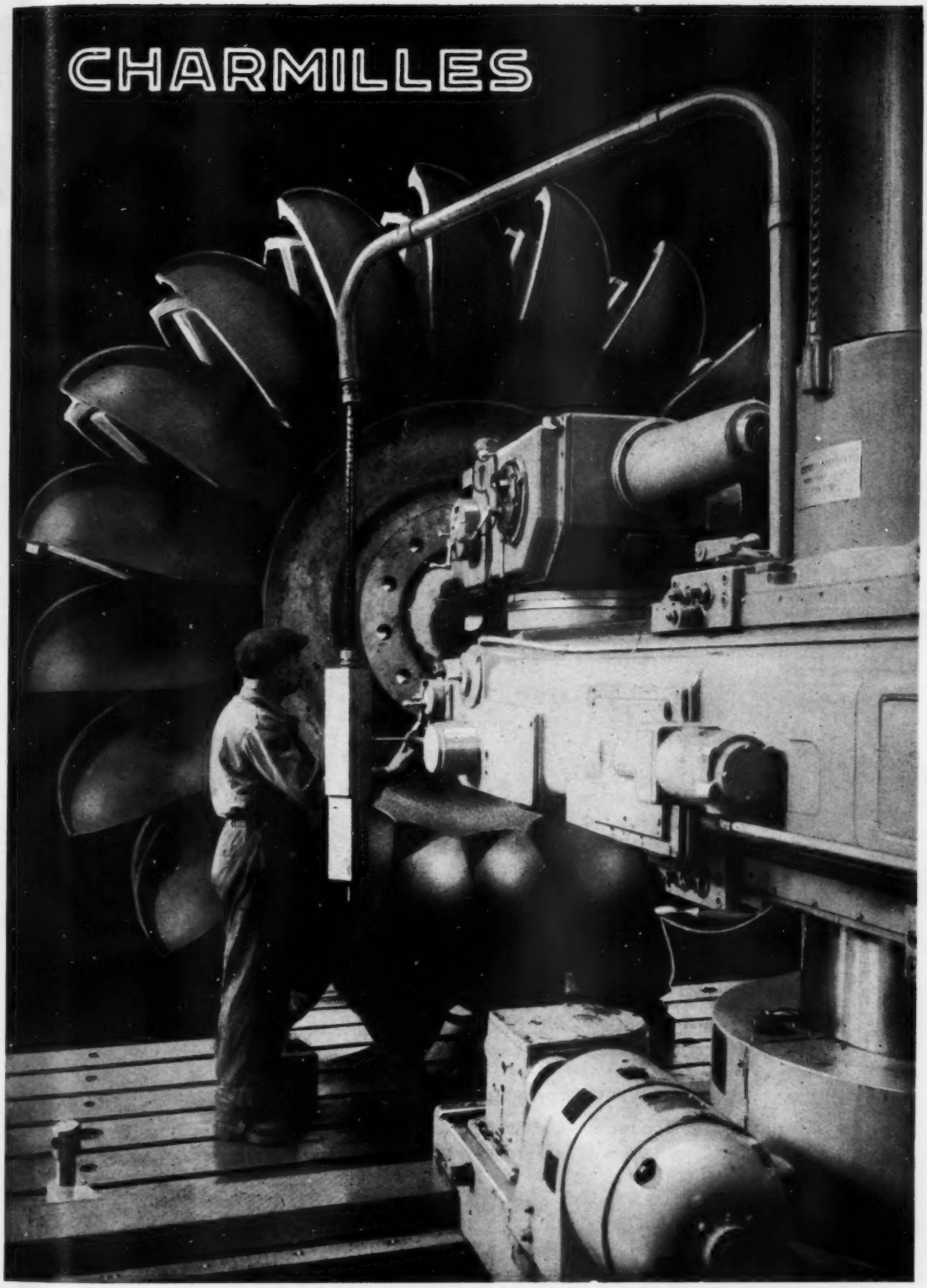

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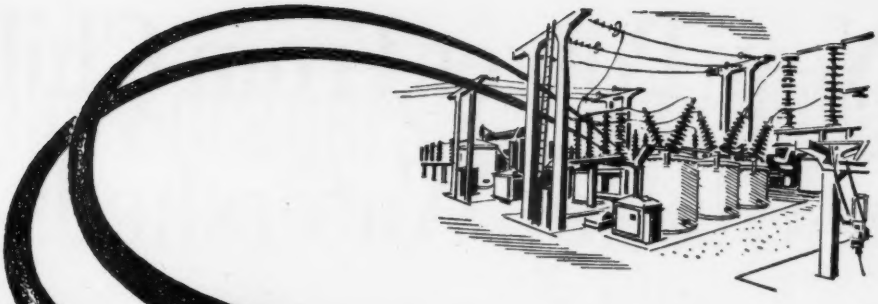
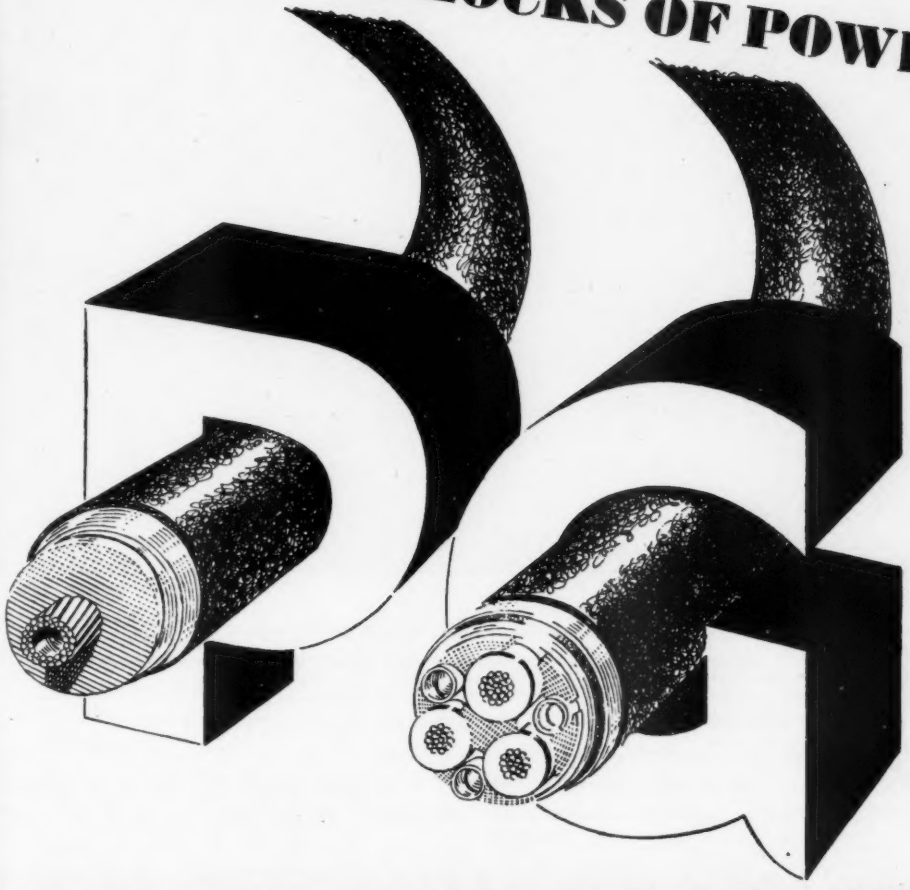


FOR LARGE BLOCKS OF POWER



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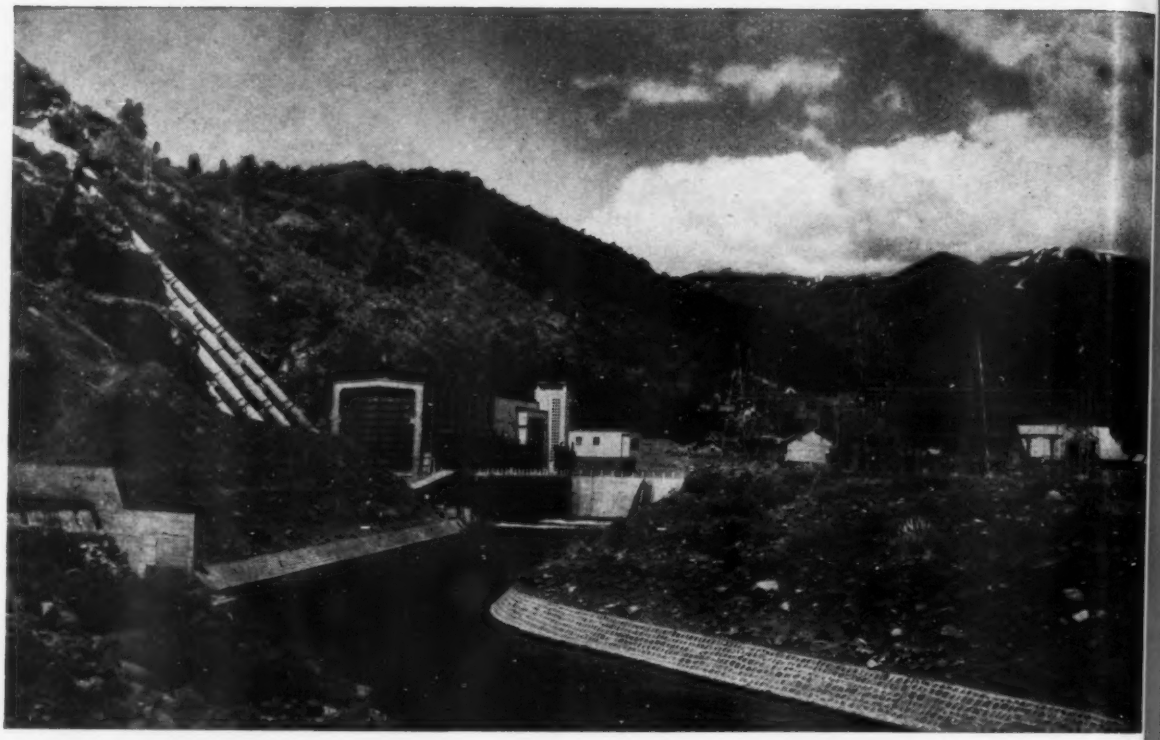

Chile is building a series of hydro-electric stations to provide sources of inexpensive power for industry and transportation, utilizing glacial watersheds in the Andes. The first two stations to be built and put in operation were Abanico and Pilmaiquen. Chilean engineers surveyed their country's potentialities . . . picked sites for development at the lowest cost and greatest efficiency. Then G-E engineers teamed with Chilean engineers, gathered data on the spot, designed, built and tested the electrical equipment.

These hydro-electric stations are one example of G-E installations located throughout the world.

EQUIPMENT INSTALLED General Electric equipment installed at Abanico and Pilmaiquen consists of generators, switchgear, control, transformers. Abanico's four 21,500-kva water wheel-driven generators now produce 86,000-kva at 13,200 volts, 50 cycles. This is stepped up to 154,000 volts for transmission. Part of this power supplies the new Huachipato steel mill, also G-E equipped.

COMPLETE ENGINEERING SERVICE G-E facilities and representatives stand ready to help you with every electrical need and problem. Get the facts from your nearest G-E representative. Or write International General Electric Co., Apparatus Sales, 570 Lexington Ave., New York 22, N.Y., U.S.A. 1A-53-206

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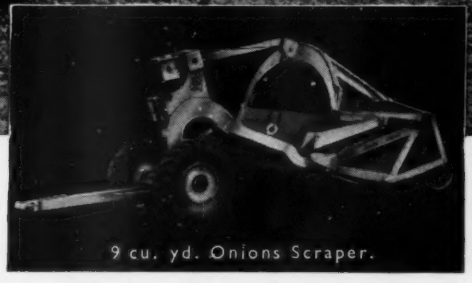
– U. S. A. –

Onions Scrapers are way ahead

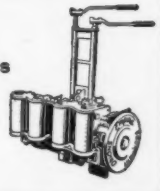
The 13 cu. yd. Onions Scraper in action with the Vickers VR·180 Tractor

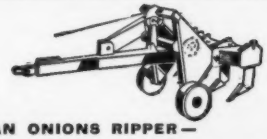


9 cu. yd. Onions Scraper.

Onions Scrapers are made in 3, 4, 6, 9, 13 and 20 cu. yd. sizes. Tractors equipped with Onions Scrapers give faster production and lower operating costs. 6 cu. yd. models and over are equipped with a 3-piece cutting edge tipped with wear resisting alloy ; two sets of end pieces are provided for either digging or levelling.

ONIONS CONTROL UNITS
for finger-tip control of heavy earth-moving equipment.





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another leading design in earth-moving equipment. Available in sizes to suit all tractors.

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- *Ample tyre equipment, including extra large rear tyres for maximum flotation.*
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- *Balanced draw bar for quick attachment to tractor.*
- *Low pressure greasing on all wheels preventing over greasing and excessive wear on oil seals.*
- *Safety lock on apron when wide open for maintenance.*

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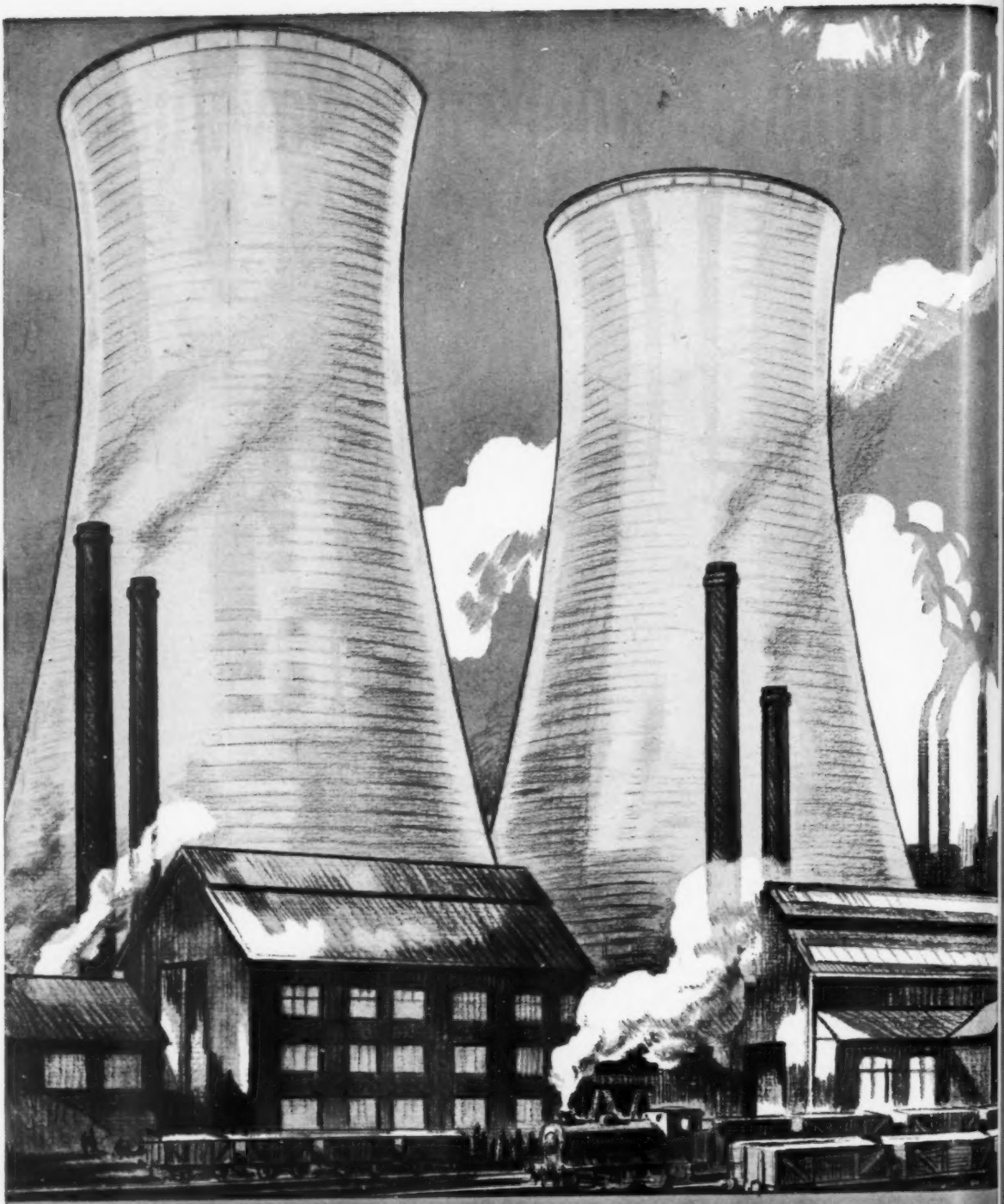

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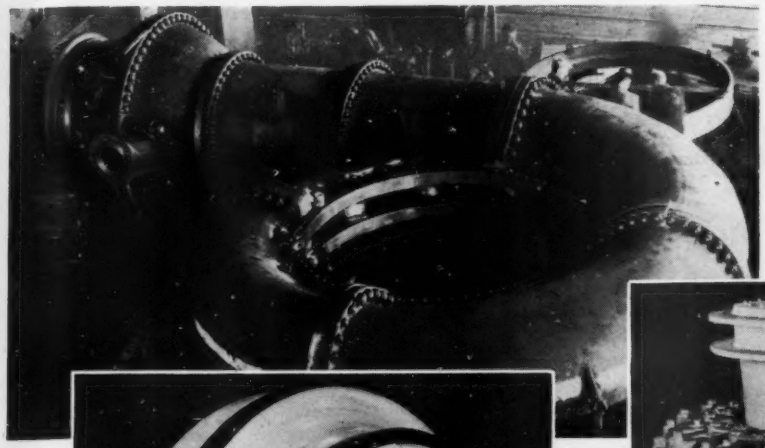
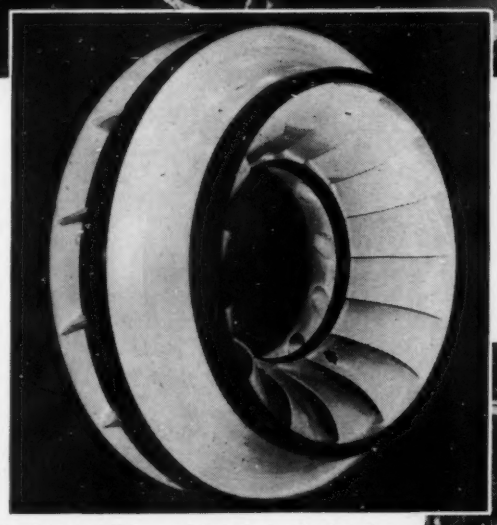
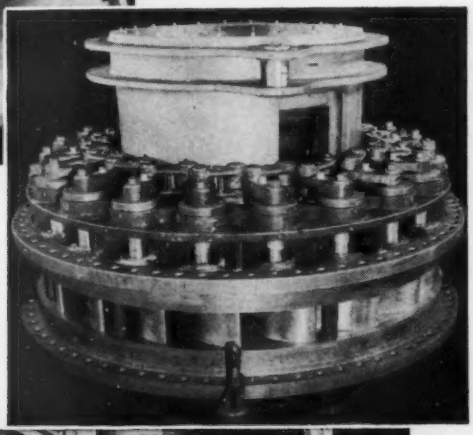
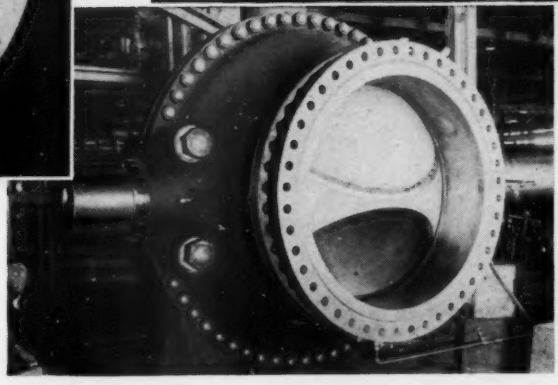


A high head Francis turbine recently put into service in Canada, built by Dominion Engineering, manufacturers for over thirty years of the famous Dominion Turbines—Francis, Propeller and Impulse types—which are harnessing more than half the water power developed in Canada.







Top Left—Spherical Valve and Spiral case undergoing shop tests.

Left Centre—Stainless Steel Runner.

Right Centre—Turbine Gate Mechanism Assembly.

Bottom Right—56" Diameter Spherical Valve.

DESIGNED AND BUILT BY

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CABLE: DOMWORKS

Arrol:

experience of the variety of problems peculiar to hydro-electric power generation schemes is evidenced in many of the world's most modern installations

Pipelines

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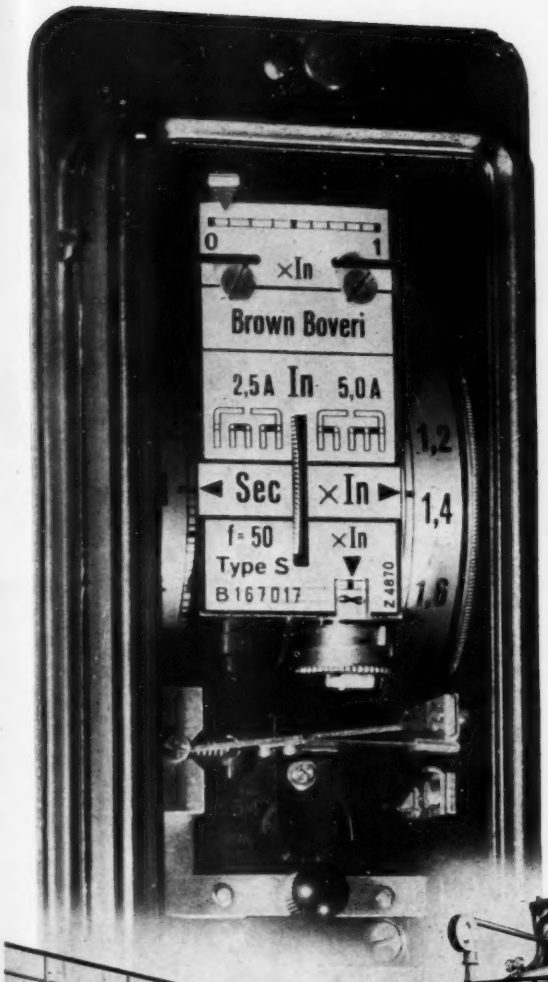

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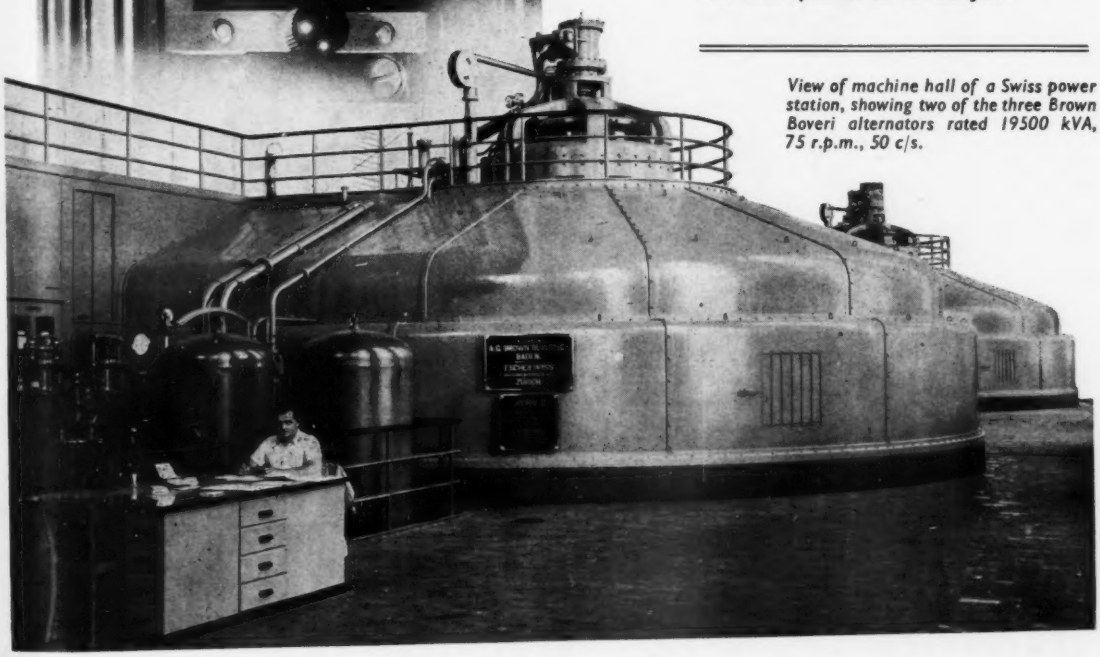
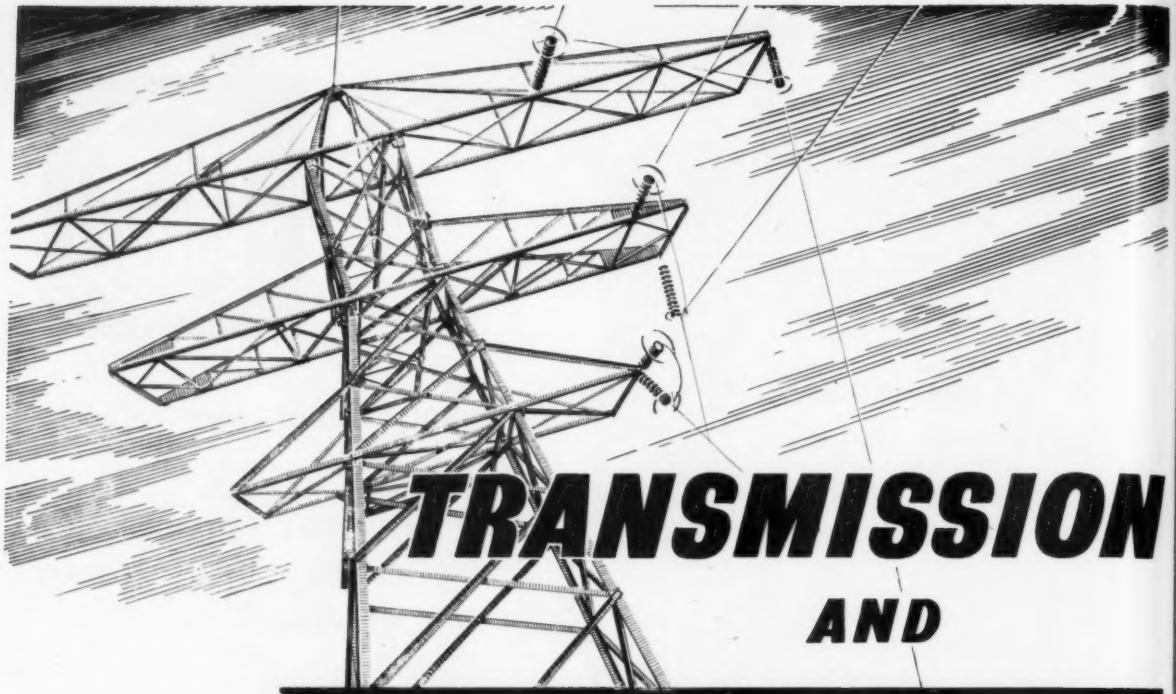
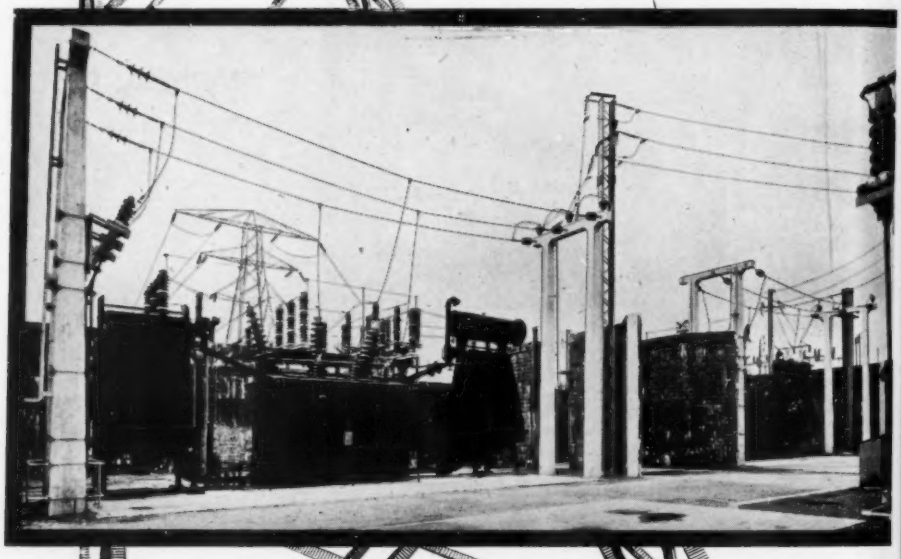


View of machine hall of a Swiss power station, showing two of the three Brown Boveri alternators rated 19500 kVA, 75 r.p.m., 50 c/s.



TRANSMISSION AND



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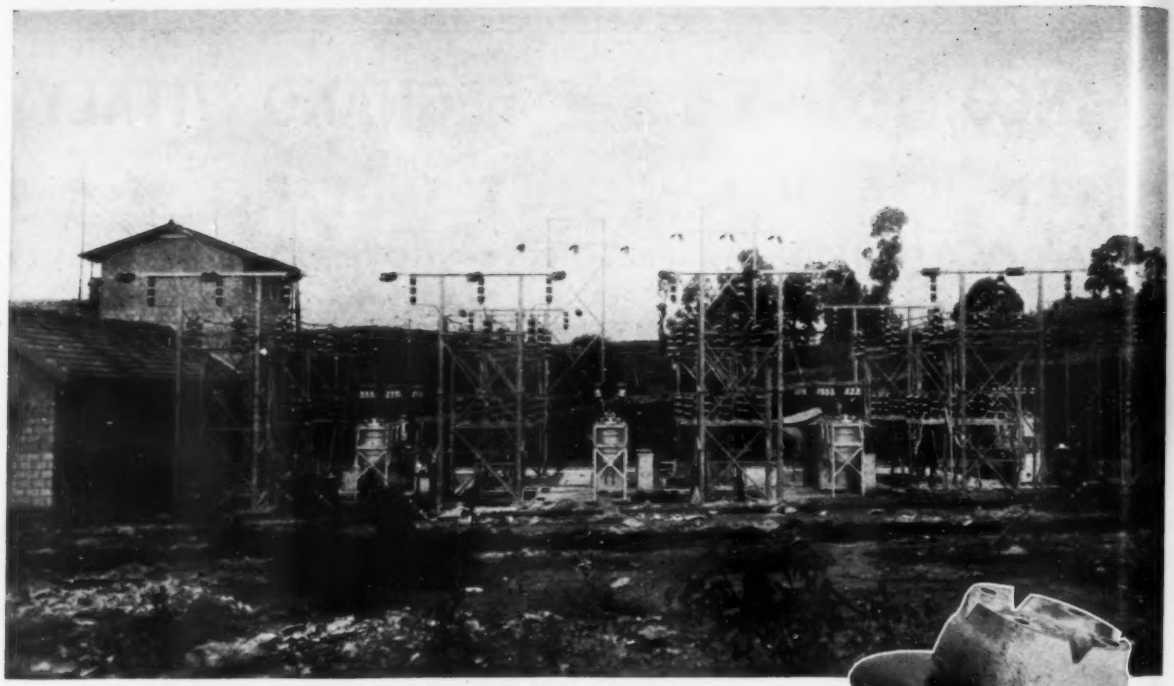

(Photograph reproduced by courtesy of Messrs. Metropolitan Vickers Electrical Co. Ltd.)

The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

S.P.P. POST INSULATORS were specified for all the 66kV outdoor switchgear on the Pallivasal Hydro Electric Scheme

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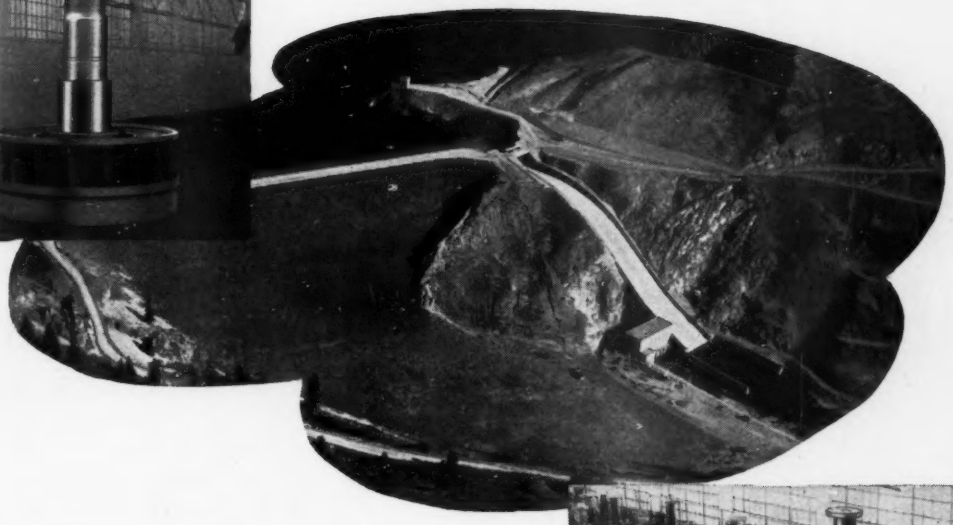

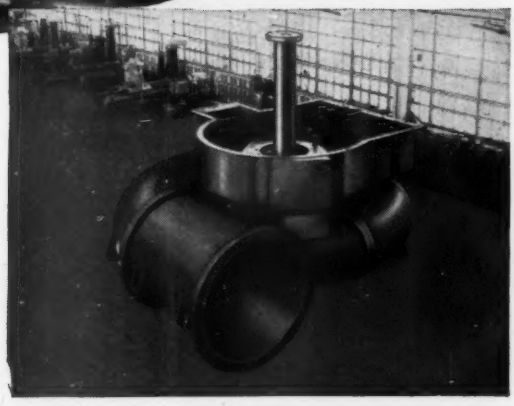

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Anderson Ranch Dam, located on the Boise River in Idaho, U.S.A., is the highest earth-fill dam in the world. Two Leffel Turbines are installed in the Anderson Power Plant which provides power for the surrounding area. The turbines are of the cast steel spiral case, vertical Francis type and each is maximum rated at 28,250 HP, under 324 ft. net head, speed 277 RPM.

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When you consider turbines for *your* power project (whether it is a new installation or the expansion of an existing installation) we ask you to keep in mind the services which are offered by Leffel. Our 91 years of experience, our large modern plant, our thorough workmanship—all are ready to serve you.

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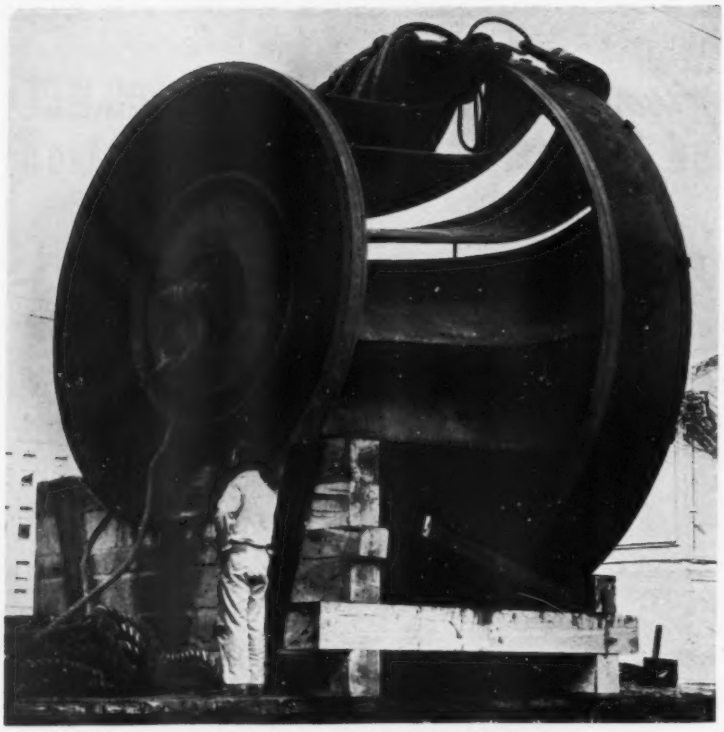

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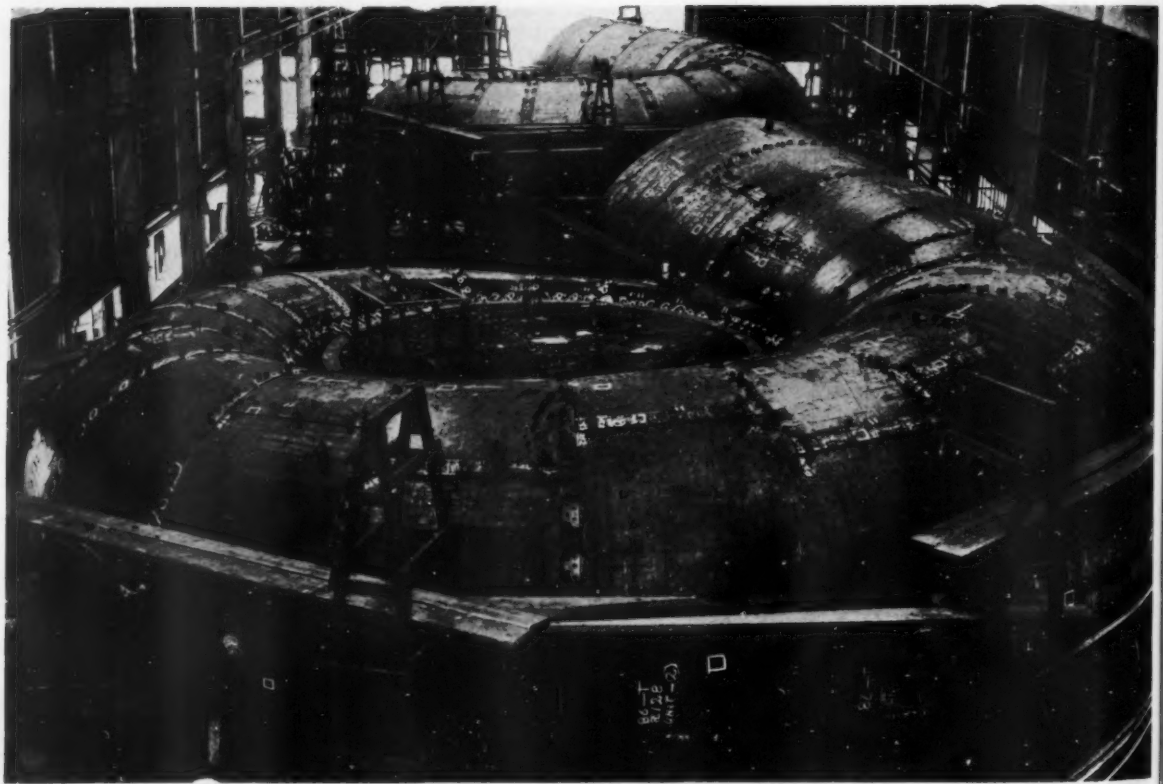
OVER EIGHT MILLION HORSEPOWER

The Newport News Shipbuilding and Dry Dock Company has received orders for the building of hydraulic turbines aggregate rated output of 8,135,000 horsepower.



ASSEMBLY OF SPIRAL CASINGS FOR C. J. STRIKE DEVELOPMENT

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Dam Building

and similar work . . . . .

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on a
very small erection area

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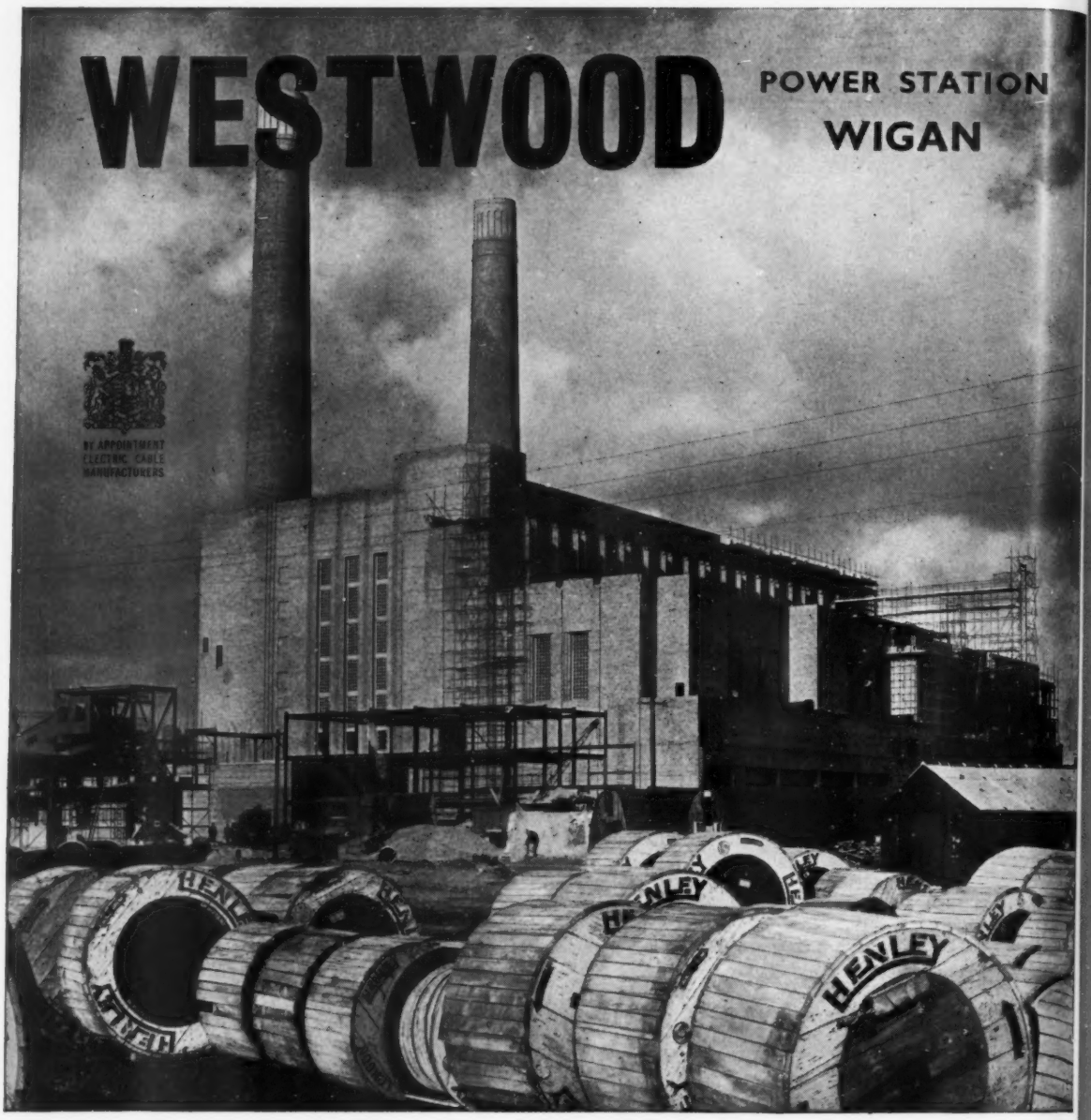

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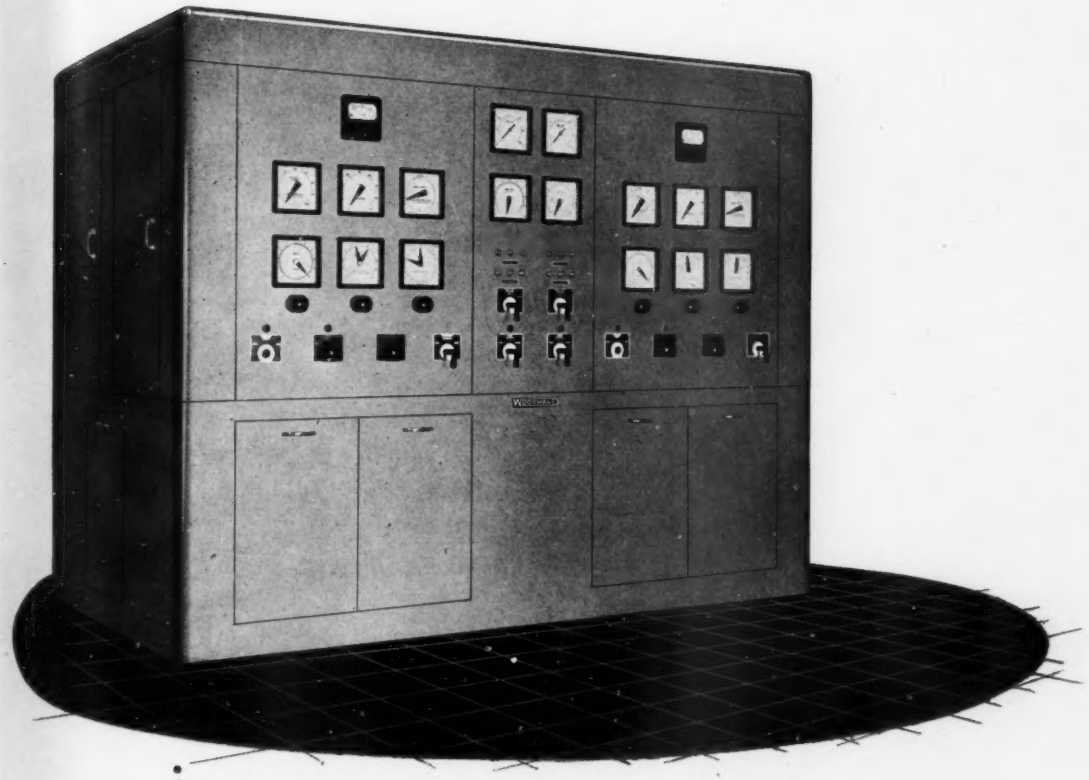

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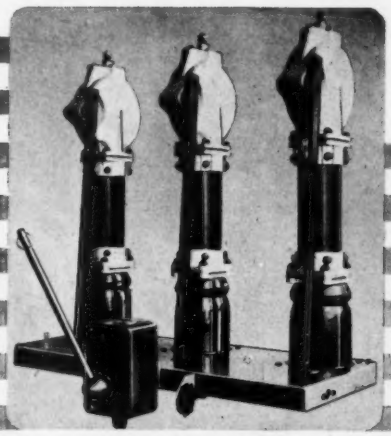

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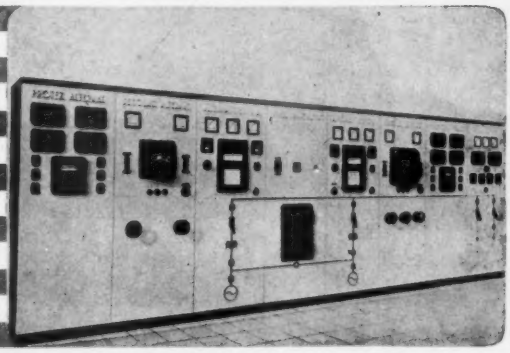

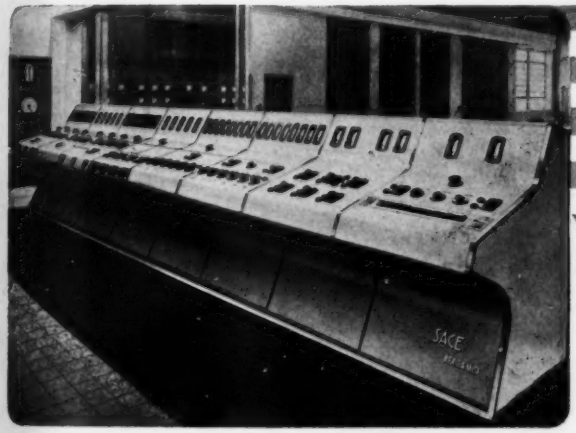

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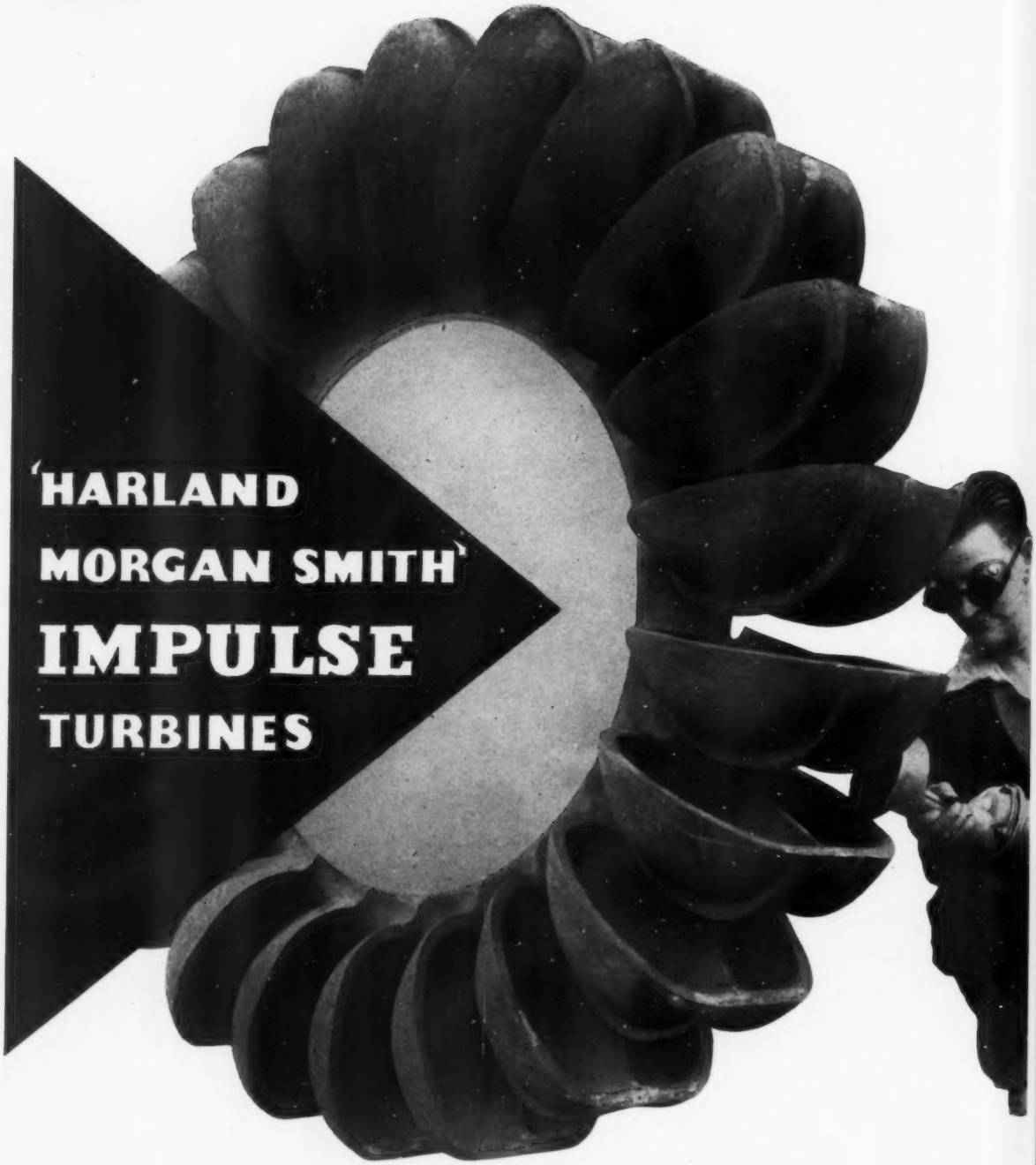

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CONTENTS FOR MAY, 1953

Editorial: Roof Bolting for Tunnel Support - - 161

Editorial Notes - - - - - - 162

Snowy Mountains—II - - - - - 164

Overflow-Type Surge Tanks - - - - 173
By Prof. L. Escande

Book Reviews - - - - - - 176

A New Type of Run-of-River Power Station - - 177
By Alexander B. Schulz

Salmon Ladders and Fish Passes - - - 180
By Eric Hardy, F.Z.S.

Book Reviews - - - - - 185

The Tobique Narrows - - - - - 186
By H. G. Cochrane, M.E.I.C.

Water-Turbine Governors and the Stability of Hydro-Electric Plant—IV - - - - - - 191
By N. G. Dennis, M.A., D.I.C., A.M.I.Mech.E., A.M.I.E.E.

Abstracts from the World Technical Press - - 196

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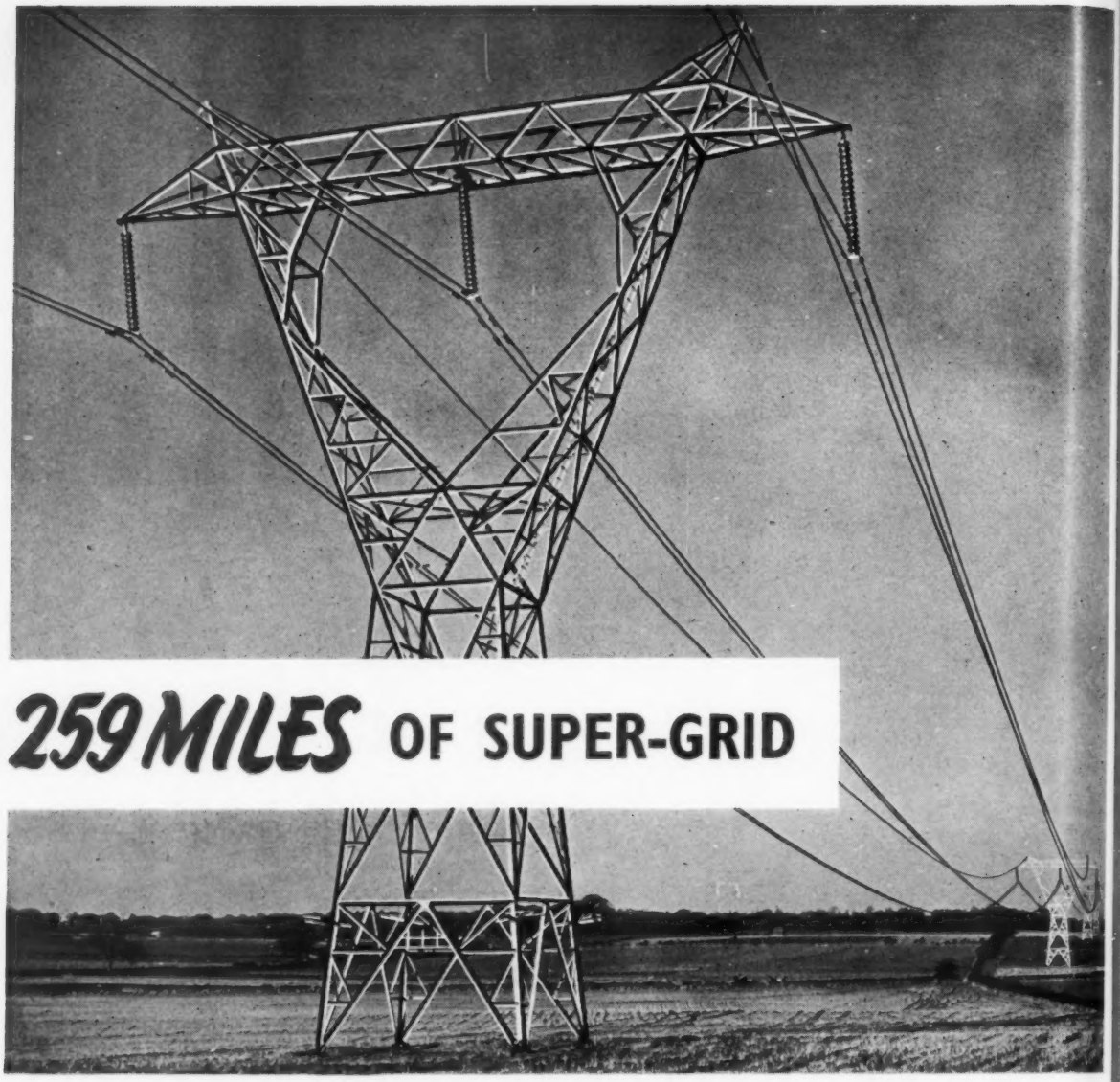

259 MILES OF SUPER-GRID

by the **BICC GROUP**

The first section of the British Electricity Authority's new 275 kV Super-Grid—the 20-mile single circuit length from Staythorpe to Barnby Moor (shown here)—was constructed by the BICC Group. The conductors were supplied by BICC, a special feature being the twin conductor formation introduced for the first time in this country. The towers were designed and supplied by Blaw Knox Ltd.

In addition, the BICC Group have contracts in hand for double circuit sections of the new Super-Grid totalling 239 miles. These are: from Stella (Newcastle) to Thirsk (62 miles); from Staythorpe to Elstree (114 miles); and from Drakelow Power Station (Burton-on-Trent) to Carrington (Manchester) (63 miles).

The BICC Group—incorporating BIC Construction Co. Ltd.—are specialists in steel tower fabrication and the construction of high voltage overhead transmission lines, and undertake work of this nature in all parts of the World.

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Roof Bolting for Tunnel Support

IN the United States in recent years a good deal of attention has been given by mining engineers to the technique of supporting underground excavations by roof bolts. This method of securing ground is by no means new, and indeed, in certain metalliferous mines a few applications can be dated back to 40 years ago. In these instances, however, the method appears to have been restricted to meeting some special difficulty and was never used systematically as the main means of support. These early trials nevertheless proved that in certain conditions roof bolting constituted a relatively cheap method of making a gallery roof permanently secure.

A city like New York with a population of between 7 and 8 millions consumes daily enormous quantities of water, and for many years the aqueducts feeding the supply system have undergone constant expansion. The East Delaware tunnel, at present under construction, is the latest addition to this system and will have an ultimate length of 25 miles through the Catskill mountains, traversing shales and sandstones of the Devonian Period. Cross bedding is considerable and numerous lenses have been encountered which have disturbed the normally uniform and almost horizontal stratification.

Roof bolting was tried experimentally at the outset and although the merit of the system was recognised and fair success was achieved, it was not considered that the results afforded the desired degree of protection which was sought. The chief fault in this preliminary work appeared to lie in the fact that the bolts were not inserted quickly enough as the excavation proceeded, and thus allowed strata flections to develop, leading to weaknesses caused by separation of the laminae.

As a result of an inspection made in February 1951 the U.S. Bureau of Mines made a series of recommendations which resulted in a complete revision of the system in use. The new specifications provided for 6 ft. long bolts, 1 in. nominal diameter, with a 5 in. rolled thread at one end and a 6 in. slot cut in the other, and for the bolts to be inserted during the face-drilling phase of each operation cycle. The wedges for the slots were $\frac{3}{8}$ in. thick and tapered along their whole length (6 in.). In the headings track-mounted drill jumbos are used, provided with six percussion-type drifters for the excavation, and two drifters, operating as a unit, for the roof-bolting holes. The headings are driven to an approximate diameter of $13\frac{1}{2}$ ft., and the finished tunnel, which is essentially of the pressure type and concrete lined, will have a finished diameter of 11 ft. 4 in.

Every endeavour is made to maintain a well-co-ordinated cycle of operation, with the drilling and roof bolting, blasting, scaling, mucking and track laying following each other with a minimum of delay. Each cycle results in an average advance of 8 ft. and about six cycles are completed per heading every 24 hours. At the beginning of a cycle, as quickly as the drill jumbo is moved up to the face, the roof-bolting crew retighten all the bolts set during the previous cycle, working from the upper deck of the jumbo and a flat car attached to the rear. Two bolt holes, 5 ft. 10 in. deep, are then drilled simultaneously, about 40° from the horizontal and about 5 ft. 6 in. from the roof centre line. These holes, it should be stated, are spotted to coincide with the end openings of a 6 in. channel-section mine tie, 5 ft. or 9 ft. long according to circumstances. Subsequently two roof bolts, with the wedges placed in the slots, are inserted in the holes and the nuts threaded about $\frac{1}{2}$ in. on to the protruding ends. The bolts are then driven to security with the drifters and threadless-type dollies welded to short drill rods. After removing the nuts the channel is placed in position, washers threaded on and the nuts tightened up with a pneumatic impact wrench. The intermediate holes, 2 ft. 4 in. apart, are then drilled and bolted, using the channel section as a template.

Not less than five ties, running parallel with the axis of the tunnel and about 2 ft. 6 in. apart, are inserted in the roof, covering an arc of about 100° or roughly 11 ft. Finally, at suitable intervals, so as not to interfere with the normal operational cycle, gunite is applied, $\frac{3}{4}$ in. thick, to the bolted-roof section and to some distance below. This is applied as

quickly as circumstances allow as it effectively checks the tendency that most shales and sandstones have to slake and fritter off when exposed to air and moisture.

In weighing up the advantages of this system it is notable that in an operation requiring nearly half a million man-hours per annum, there was not a single lost-time accident under any section of the roof protected by bolts. A further advantage lies in the fact that in the sections of the tunnel supported by steel arches the lagging sheets and all loose material must be removed before the concrete lining is inserted. Where the roof bolts have been inserted, however, there is no material to handle, no loose rock to remove, and the workers have excellent overhead protection. Unfortunately comparative time studies were not made, but the saving in man-hours in handling and inserting the roof bolts, compared with erecting the steel sets and lagging, is beyond question. Also much smaller storage space is necessary both on the surface and underground.

The success which has attended this experiment is attributed to the time and care taken to formulate the specifications, to the continuous supervision and inspection that were maintained and to the excellent co-operation that was manifested by all concerned.

Philpott Dam

THIS 13 million dollar project has now been completed and its associated power station is expected to go on load shortly. It constitutes one of a series of dams planned to control the Roanoke river and its tributaries, and in addition to providing this important service with its capacity of 250,000 acre ft. will also contribute some 13,400 kW of additional capacity to the electric supply system. Over 80,000 acre ft. of storage space will be available for flood control and it is estimated that this will leave an ample margin to contain any floods equal to those that have occurred for more than a decade.

The dam is just short of being 900 ft. in length and rises to a height of 220 ft. above riverbed level. As might be supposed ample provision has been made for flood control, the spillway being 120 ft. wide and having a discharge level 7 ft. below the level of the dam crest. In addition, three hydraulically-operated sluice gates are provided, each measuring 5 ft. 8 in. wide by 10 ft. high.

The Shawinigan Water and Power Company

ACCORDING to the company's annual report, the Shawinigan Water and Power Company's gross revenue from sales of electricity during 1952 was the highest in the company's history, at $37,556,711, and total net earnings from all sources amounted to $1.91 per common share, compared with $1.84 in 1951. The increase in the company's revenue from electricity sales, of 8·4 per cent., was made possible principally by abnormal rainfall during the year in the St. Maurice watershed. With a supply of water almost unprecedented in the tributaries and reservoirs, the Shawinigan company was able to increase power production in the six St. Maurice river developments to such an extent that purchase of electricity from other power producers was reduced, substantial amounts were sold as secondary power, and the amount of water in storage reservoirs at the end of the year was increased by 35·2 per cent. over that at the end of 1951.

Because such water conditions are not of a regularly recurring nature, the company established a water-storage equalisation reserve of $1,000,000, or a net amount of $524,000 after deduction of the applicable income and profits taxes, to be available to equalise earnings in future periods of sub-normal rainfall. Operating expenses, excluding depreciation, were 7·3 per cent. higher than in the year before, due to higher wage levels, increased cost of materials, and greater municipal taxes. Provision for depreciation was increased from $5,600,000 to $6,142,000.

Aswan Dam Power Development

PROPOSALS to derive power from the water impounded by the Aswan dam have been debated since 1932. This dam was built between 1898 and 1902 and has twice been heightened, the last occasion being in 1933 when the storage capacity was increased to 4,000 million acre ft. It was essential that any power development should be so designed that the structure of the dam remained unaffected, and according to a recent proposal—itself a modification of the original one—the turbines were to be supplied by pipes passing through the existing sluices. Four of these pipes were to serve one turbine, and each turbine was to have its own surge tank. Seven 65,000 h.p. main turbines were ordered, to be coupled to 49·5 MVA alternators, and two 16,000 h.p./13·5 MVA auxiliary sets.

Much uncertainty has existed as to the outcome of these proposals owing to the changes in the Egyptian Government, but a contract has now been placed for the main civil-engineering work for a scheme that differs radically from the one just outlined. In the scheme adopted the power station will be located away from the immediate vicinity of the dam and will involve the construction of forebays, cofferdam, a new intake dam and four tunnels, leaving the Aswan dam undisturbed. This work will be carried out jointly by two French firms, Grands Travaux de Marseille and Schnieder et Cie, the value of the contract being E£10,342,000. The turbines are being built by K.M.W., Escher Wyss, and Charmilles, and the alternators by A.S.E.A., Brown Boveri, Oerlikon and S.A. des Ateliers de Secheron.

The principal consulting engineers are Messrs. Kennedy and Donkin, and the scheme is scheduled to commence operation in July 1957.

New Rhône Dam

THE French Premier, M. Mayer, inaugurated recently the work on a new dam which is to be constructed at Rochemaure, near Montélimar, to harness the Rhône between Génissiat and Donzère-Mondragon. The new scheme will also be on the grand scale and is estimated to cost about £60 million, and to contribute 1,600 million kWh to the French grid. A head of 58 ft. will be exploited.

In the course of his remarks on this occasion M. Mayer stated that the Montélimar dam marked the beginning of a second plan for the modernisation and reconstruction of France. The Monnet plan, he added, had enabled French economy to be restored at a time when the country was not only bearing the

weight of events in Indo-China but was also building up strengths for the defence of Europe. Now the second stage must be begun, for it was inevitable that France should retain her place in the Atlantic alliance and to do this she must preserve " the living countenance of a country that does not intend to give up but ever to march forward."

Sweden Plans Largest Station

THE Swedish State Power Board has prepared plans for a station at Stornorrfors on the River Ume in the south of Sweden. It will be the largest station in the country, and will have a capacity of 375 MW as against the 350 MW at Harspränget, which is at present the largest plant in Sweden. The Stornorrfors station will be of the underground type, and will contain three generating sets operating under a head of 240 ft. A discharge tunnel, 2½ miles long by 3,765 sq. ft. cross section, will be required, and will be the largest to be constructed in that country. The station is scheduled for completion in 1959.

Northern Ireland Surveys

HYDRO-ELECTRIC engineers surveying Northern Ireland's water-power resources have now completed full-scale plans for harnessing the River Bann at Carnroe, near Kilrea. The Ulster Ministry of Commerce are considering the scheme, and an order to embark on the initial operations may shortly be issued. The possibilities of a station on the Mourne River at Sion Mills are also being investigated, but a former river bed has been found concealed under the present one, and additional borings and a geophysical survey will have to be carried out before the final scheme can be drawn up.

If the proposed schemes go forward they will be the first to add water power to the province-wide grid operated by the Electricity Board for Northern Ireland. It is estimated that the Bann and Mourne together can provide up to 20,000 kW.

Bersimis Project, Quebec

THIS development, situated about 100 miles north of Baie Comeau on the north shore of the St. Lawrence River, is designed to increase Quebec water-power output by 16 per cent. and will have an installed capacity of 1,000,000 h.p. The first units of the power station are expected to be brought into commission in 1956 and will harness the waters of the turbulent Bersimis river which flows from Lac Casse in a narrow gorge and falls some 600 ft. in a distance of 10 miles. A rock or clay-filled dam will be erected and will divert the water through a 6½ miles long tunnel driven in the solid about 1,000 ft. below the surface. Bersimis was not scheduled for completion until 1960 but a revision of the Quebec Hydro-Electric Commission's plans advanced this date and the Commission instructed their consulting engineers, H.G. Acres & Company, accordingly. To expedite matters the services of the Photographic Survey Corporation Limited of Toronto were called upon and some 275 sq. miles have been surveyed from the air. A map has now been produced to a scale of 1/12,000 with the contours plotted at 20 ft. intervals and the main geological features established. A suitable route for the 100 mile transmission line has been established by the stereoscopic examination of aerial photographs, this route following rocky ground as far as possible and consisting of long straight sections with a maximum span of 1,200 ft. between towers.

Standard tariffs in Spain

THE Spanish Government has made a decree establishing a standardised system of electricity tariffs throughout the country, the aim being to finance expansion of power generating resources. Following a rise of 15 per cent. in consumption in 1952, the Minister of Industry declared that there would be an unprecedented series of restrictions during the next five years unless at least 300,000 kW of additional generating capacity could be installed. The decree also provided for the abolition of surcharges on all electricity accounts which, since 1949, had been devoted to the alleviation of unemployment in industries affected by power cuts.

Flood Prevention in Hungary

PREVENTATIVE measures in Hungary, due for completion by 1954, are expected to eliminate danger of flooding from the Rivers Danube and Tisza which in the past 100 years have inundated hundreds of thousands of acres no less than seventy times. Dykes have been built along 2,275 miles of river bank to a height of three to five feet above the highest flood level expected. These are of earth and are mostly surfaced with brick or stone.

To safeguard areas not yet completed, there is in Budapest a Central Organisation for Emergency Flood Protection, which maintains a park of fast lorries which can rush all necessary equipment and manual assistance to any threatened area within four hours.

The safety of the flood-protective system will be further increased when the Tisza barrage is completed in upper Hungary. This dam, which will retain a large volume of the Tisza river water for hydro-electric and irrigation purposes, is now at an advanced stage. The three sluice gates, measuring 120 ft. across by 25 ft. high, are now in process of being erected.

Sixth Canadian International Trade Fair

THE sixth Canadian International Trade Fair, Toronto, June 1-12, will be the largest in the history of the event. The bulk of the bookings came from Canadian firms who, at this date, are known to be occupying approximately 90,000 sq. ft. of the stand space. Next is the United Kingdom with approximately 56,000 sq. ft.

To give the world's buyers more information about Britain's products and services in the widest possible varieties of fields, a number of the United Kingdom's leading publishers of business journals, including the publishers of WATER POWER, are combining in the display of no less than 55 of their finest and most widely read technical, trade and specialised publications. Twenty other countries will be exhibiting, including Germany, U.S.A., India, Eire, Sweden, Netherlands, Japan, France, Belgium and Denmark.

Fig. 11. Region of Spencer's Creek dam site, looking downstream

Snowy Mountains

In this second article we discuss the hydrology of the Snowy Mountains district and give a summary of the projected works involved in this huge development.

PART TWO

ONE of the major difficulties facing the Technical Committee during the preliminary investigations was that hydrological data relating to the Snowy Mountains Area were far from complete. Data from rain gauging were soon discovered to be of very little value, except possibly for checking assumed run-off figures, because the gauges were not only few and far between but most of them were in snow country. It was therefore decided at an early stage to ignore precipitation data and to concentrate on river-flow and run-off figures.

The existing river-gauging stations differed considerably in their estimated reliability, and adjustments were made to the less reliable figures to bring them into harmony with more reliable readings from other stations on the same river system. In any case the information related to the yield from relatively large areas, and was of little value in itself for arriving at the power potentialities in the upper reaches. Its value, therefore, was believed to lie in its use for checking any assumptions made as to the yield of the relatively small areas at the heads of the catchments. The problems were chiefly to determine variations of run-off over the catchments, and it was decided to attempt to derive sufficient information to enable lines of equal run-off to be drawn on the catchment plan.

The procedure now to be described used only the preliminary figures available to the Technical Committee, and these have since been revised in the light of more detailed investigations, but the method warrants description as it is of unusual interest.

The available gaugings were dissected as far as possible to enable the average run-off, both from corresponding portions of adjacent catchments and from different parts of the same catchment, to be compared. This analysis is given in Table II, and as will be seen, there is a great variation in run-off within the upper catchments of adjoining areas.

In the Snowy Mountains Area the prevailing direction of the weather is from the west, and precipitation is due predominantly to the chilling of the moisture-laden air by deflection over the high country, and is therefore a function of the height, modified by shielding effects. Seeing, also, that the run-off at high altitudes will be a larger proportion of the total precipitation than is that at low altitudes, the run-off may be expected to be even more

TABLE II

	Catchment River	From	To	Area sq. m.	Adopted Yield acre ft.	Average Run-off feet
1	Swampy Plains	Source	Khancoban	223	510,000	3·59
2	Swampy Plains	Khancoban	Bringenbrong	114	78,000	1·07
3	Murray or Indi	Source	Bringenbrong	490	400,000	1·27
4	Tooma	Source	Possum Pt.	199	387,000	3·04
5	Tooma	Possum Pt.	Warbrook	536	207,000	0·60
6	Snowy (Central Area)	Source	Jindabyne	343	540,000	2·46
7	Eucumbene	Source	Eastbourne	288	195,000	1·06
8	Crackenback	Source	Creel	99	215,000	3·40

TABLE III

	Catchment	Areas at Various Levels (square miles) under 2,000 ft.	2,000 to 3,000 ft.	3,000 to 4,000 ft.	4,000 to 5,000 ft.	5,000 to 6,000 ft.	6,000 to 7,000 ft.	over 7,000 ft.	Total area sq. miles
1	Swampy Plains	26·1	38·4	43·0	38·9	58·6	17·5	0·5	223
2	Swampy Plains	47·0	30·4	18·6	13·7	4·3	—	—	114
3	Murray	71·4	118·7	123·9	146·3	27·6	2·1	—	490
4	Tooma	31·6	45·5	39·7	56·0	25·5	0·7	—	199
5	Tooma	214·0	248·2	58·4	15·4	—	—	—	536
6	Snowy	—	12·8	118·8	93·5	92·3	25·3	0·3	343
7	Eucumbene	—	—	138·5	125·3	24·2	—	—	288
8	Crackenback	—	1·0	21·9	33·1	35·1	7·8	0·1	99

TABLE IV

	Catchment	Run-off in Feet F	Height characteristics C_a	C_b	C_c	Ratios $\frac{100F}{C_a}$	$\frac{100F}{C_b}$	$\frac{100F}{C_c}$
1	Swampy Plains	3·59	4·03	18·6	93·4	89	19·3	3·85
2	Swampy Plains	1·07	2·61	8·3	29·8	41	12·9	3·59
3	Murray	1·27	3·40	12·9	52·9	37	9·8	2·41
4	Tooma	3·04	3·50	13·9	60·7	87	21·9	5·02
5	Tooma	0·60	2·27	6·0	15·8	26	10·0	3·80
6	Snowy	2·46	4·50	21·3	106·1	55	11·5	2·32
7	Eucumbene	1·06	4·10	17·1	74·3	26	6·2	1·43
8	Crackenback	3·40	4·77	23·6	121·2	71	14·4	2·81

dependent on height than is the precipitation.

To assist in the analysis, each catchment was therefore broken down into areas between the 1,000 ft. contours, as in Table III. To discover whether any relationship existed between run-off and height, these areas were used to determine three series of height characteristics, which were compared with the run-off (F) given in Table II. These height characteristics were based respectively on the first, second and third powers of the heights, thus:

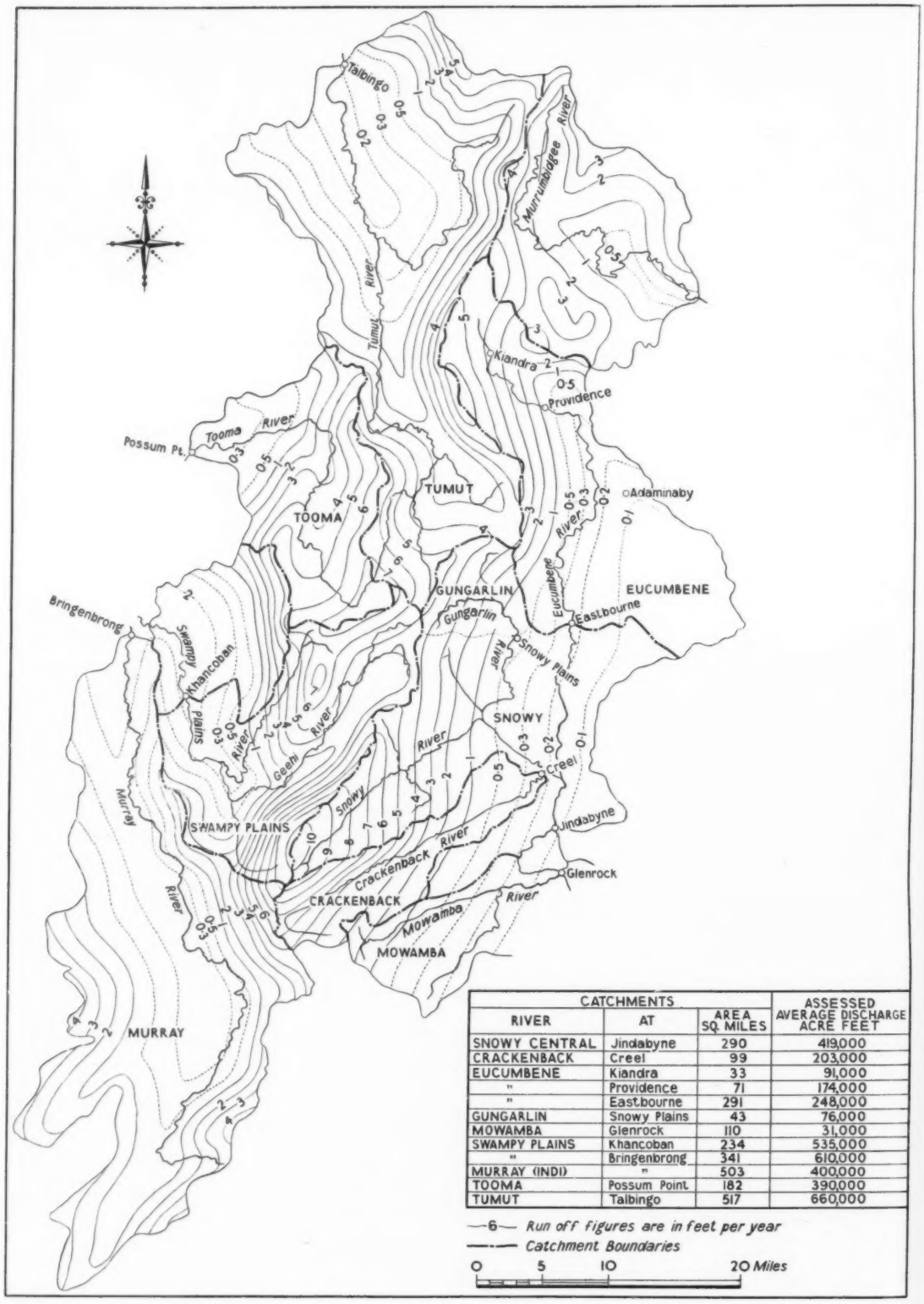
$$C_a = \Sigma ah/A,\ C_b = \Sigma ah^2/A,\ C_c = \Sigma ah^3/A,$$

where a is the area between two 1,000 ft. contours, h the average height of that area in thousands of feet, and A the total area of the catchment.

The resulting figures are set out in Table IV, from which several interesting conclusions may be drawn. In the first place, the C_a characteristic gives a wide difference between the upper and lower catchments of the Swampy Plains, the run-off here varying more in accordance with characteristic C_c. For catchments 1, 2 and 4 on the exposed westerly face of the ridge there is every indication of the run-off being a function of height, the relationship being something between the square and the cube. Catchments 6, 7 and 8, on the other hand, which are on the east, show much lower figures, indicating that the weather comes in from the west and expends itself as it passes over the ridge. Table V shows this phenomenon in striking fashion. The average F/C_c ratio for catchments 1, 2 and 4 is 4·15, and this figure is used as the basis of comparison in the Table.

Catchment 3 has a lower area, well away from the high ridges,

Fig. 12. Gauging station on Perisher Creek



CATCHMENTS			ASSESSED AVERAGE DISCHARGE ACRE FEET
RIVER	AT	AREA SQ. MILES	
SNOWY CENTRAL	Jindabyne	290	419,000
CRACKENBACK	Creel	99	203,000
EUCUMBENE	Kiandra	33	91,000
"	Providence	71	174,000
"	Eastbourne	291	248,000
GUNGARLIN	Snowy Plains	43	76,000
MOWAMBA	Glenrock	110	31,000
SWAMPY PLAINS	Khancoban	234	535,000
"	Bringenbrong	341	610,000
MURRAY (INDI)	"	503	400,000
TOOMA	Possum Point	182	390,000
TUMUT	Talbingo	517	660,000

—6— Run off figures are in feet per year
—·— Catchment Boundaries
0 5 10 20 Miles

Fig. 13. Map of Snowy Mountains region showing catchments and lines of equal run-off

TABLE V

Catchment	6 Snowy	7 Eucumbene	8 Crackenback
Ratio $100F/C_e$	2·32	1·43	2·81
Ratio 4·15 less Catchment Ratio	1·83	2·72	1·34
Distance from Ridge to centre of catchment (approx. in miles) ...	9	15	7
Decrease in Ratio/Mile ...	0·20	0·18	0·19

and the head of the river is shielded by another ridge on its western side. Catchment 5 lies mostly outside the influence of the high country.

An attempt was then made to establish a formula for the run-off from three catchments not subject to shielding, and the following was found to give quite good results:—

$$F = 0{\cdot}10\,(h+1) + 0{\cdot}55\,(h-2)^2 - 2\,(h-5{\cdot}5)^2$$

The first term expresses a general trend towards an increase in yield with height regardless of the conditions of exposure, the second term gives the rapid increase in yield with height found on the exposed western face, and the third allows for a flattening out of the run-off curve at high altitudes due to the winds deflecting round the highest peaks. The results of applying this formula to catchments 1 to 5 are given in Table VI. The discrepancy in the Murray result due to shielding of this catchment will be noticed immediately.

The excess for Swampy Plains may be due to partial shielding when the weather comes in more from the north-west than the west, and the deficiency in the upper Tooma may be due to the formula not giving a sufficiently rapid rise with height between 2,000 and 5,000 ft. Nevertheless the formula was accepted for the exposed catchments as it was deemed to be on the conservative side.

It was then decided to try to modify this formula to allow for the shielding effects on catchments 3, 6, 7, and 8, as follows:—

$$F = 0{\cdot}10\,(h+1) + (0{\cdot}55 - 0{\cdot}05M)\,(h-2)^2 - (2 - 0{\cdot}18M)\,(h-5{\cdot}5)^2$$

In this formula M is the average number of miles east of the ridge shielding the area, and the formula is based on the assumption that the weather expends itself in moving 11 miles from the ridge. As will be seen from Table VII the agreement obtained was remarkable.

TABLE VI

Catchment	1 Swampy Plains	2 Swampy Plains	3 Murray	4 Tooma	5 Tooma
	ac. ft.	ac. ft.	ac. ft.	ac. ft.	ac. ft.
Yield from Formula	554,000	93,000	700,000	330,000	214,000
Actual Yield	510,000	78,000	400,000	387,000	207,000

TABLE VII

Catchment:	3 Murray (Indi)	6 Snowy	7 Eucumbene	8 Crackenback
	ac. ft.	ac. ft.	ac. ft.	ac. ft.
Yield from Formula	432,000	548,000	193,000	217,000
Actual Yield	400,000	540,000	195,000	215,000

Fig. 14. View across the dam site at Guthega, looking upstream

As a fairly close assessment of run-off from the highest levels was required, the results from these formulae were checked by a second method of approach. This consisted in plotting curves of percentages of total yield against percentage of total area for the Swampy Plains and Tooma catchments. For each of them the total yield and that for an upper area were known, and the relatively even progression of gradients made it justifiable to assume that the curves should be "easy" ones. A comparison with curves drawn from the height formulae confirmed that the results given by the formulae were on the safe side.

All these results were finally collated and adjusted to build up the map of lines of equal run-off reproduced in Fig. 13. The accuracy of this map was felt to be ample for the preliminary investigations, as it agreed with the known data within observational accuracy, and the lines had fallen naturally into place without anything being forced to fit. Later investigations, in fact, have shown the potential capacity of the scheme to be somewhat greater than indicated by the study.

Fig. 15. Access road to Guthega dam site

Fig. 16. Workshops and barracks area at Tumut Pond

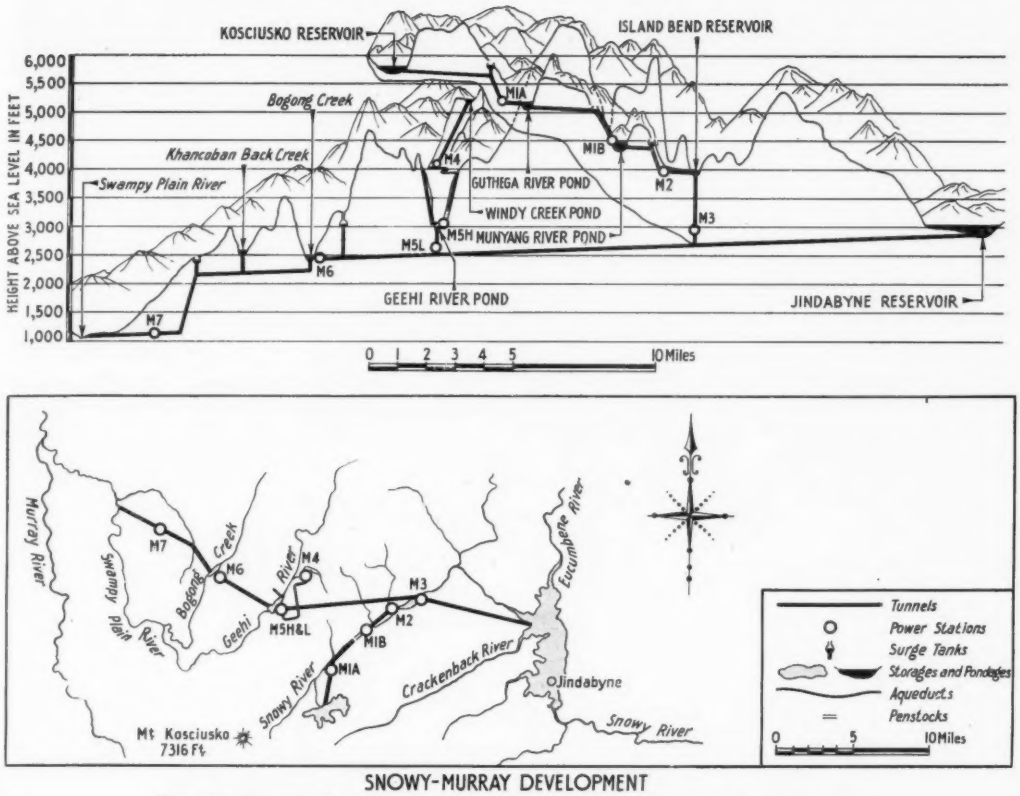
Operation with Thermal Plants

We have already outlined the existing power-supply position and have referred to the part played by hydro-electric power, particularly in the State of Victoria. The Snowy Mountains scheme is also based on the principle of joint operation with thermal stations, and is conceived as a peak-load system, leaving the base load to be carried by steam plants—which will also have to be greatly extended.

In a combined system such as this, the optimum proportion of hydro to thermal plant is the expression of an economic balance which depends, among other things, upon the shape of the load curve and upon water availability. If too little hydro-electric plant is installed it will be unable to take its full economic share of the peak loads, and it will be necessary to install more steam plant than would otherwise have been required. If the hydro-electric installation is too large there will not be sufficient water to use its capacity in times of low water, and capital expenditure will have been wasted. The Snowy proposals have been based on a ratio of 38 per cent. firm hydro-electric power to 62 per cent. thermal power. To ensure that the hydro capacity will be firm even under the worst conditions, the capacities were worked out on the basis of a synthetic year comprising the driest record for each of the twelve months. Normally, of course, this will mean that the hydro plant will be able to take a larger share of the peak loads and thus save fuel.

General Scheme of Development

The general scheme of development recommended by the Technical Committee, and now being implemented by the Snowy Mountains Hydro-Electric Authority with minor modifications, comprises two interrelated but physically separate developments. In the southern half of the area the Snowy River is to be diverted to the Swampy Plains River, a tributary of the Murray; in the northern half, the Eucumbene, which is a tributary of the Snowy, the Tooma, which is in the Murray catchment, and the upper Murrumbidgee, are to be diverted to the Tumut, which feeds



SNOWY-MURRAY DEVELOPMENT

Fig. 17. Profile diagram and map of the Snowy-Murray development

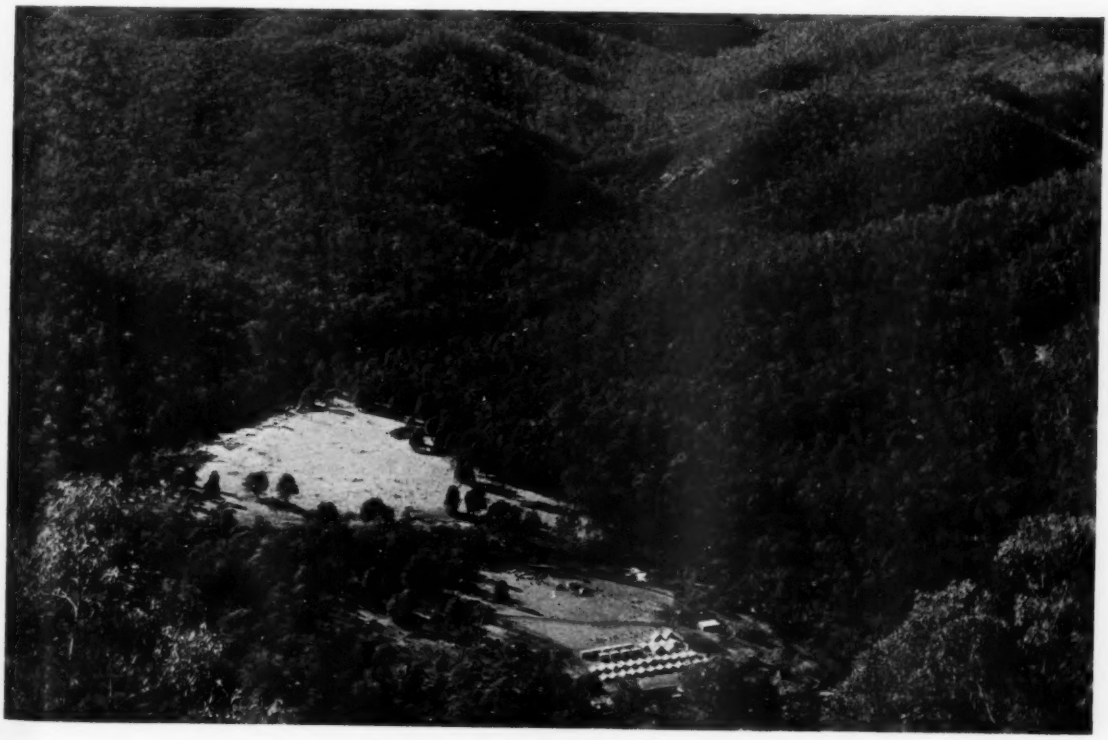


Fig. 18. Survey camp at Lob's Hole

the lower Murrumbidgee. These developments will distribute water for irrigation between the Murray and the Murrumbidgee in the desired proportion, but as the waters from both these developments are directed through natural outfalls full use can be made of them for power generation.

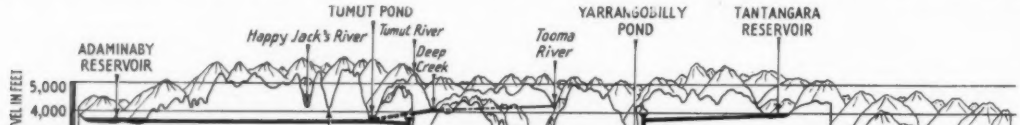
Snowy-Murray Development

This development will be in three sections, although the main diversion will produce such a large proportion of the power that the other sections may be regarded as minor additions. A schematic elevation and plan of the development are given in Fig. 17.

In the main development the Snowy River will be dammed at Jindabyne and the waters taken by tunnel to Swampy Plains, picking up waters from the Upper Snowy, Geehi, Bogong Creek, and Khancoban Back Creek on the way. These works involve the construction of a dam about 260 ft. high at Jindabyne and a tunnel about 30 miles in length, varying in diameter from 35 ft. to 42 ft., to Swampy Plains River. Sections of this tunnel will be 3,000 ft. underground. Four underground power stations will be built at intervals along its length.

The first of these power stations (M3 in Fig. 17) will be at Island Bend where the tunnel passes under the Upper Snowy River. A 1,000 ft. shaft will be sunk at this point, down which the Snowy Waters will fall to pass through turbines in a power station at the base of the shaft before being discharged into the main tunnel. A second underground power station (M5L) will be built where the tunnel passes under the Geehi River, the waters of which will fall down a

Fig. 19. Surveyors at work on the Tumut River



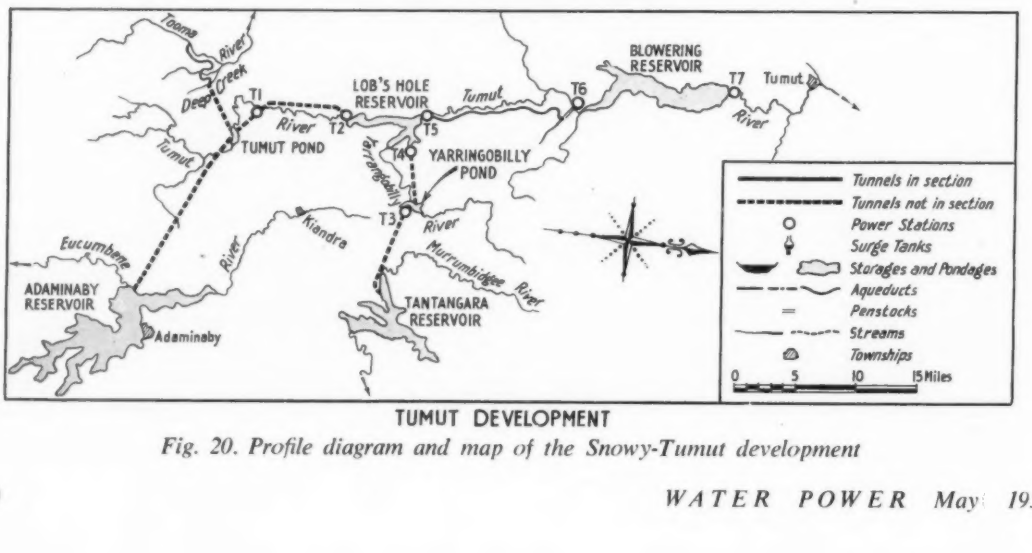


Fig. 20. Profile diagram and map of the Snowy-Tumut development

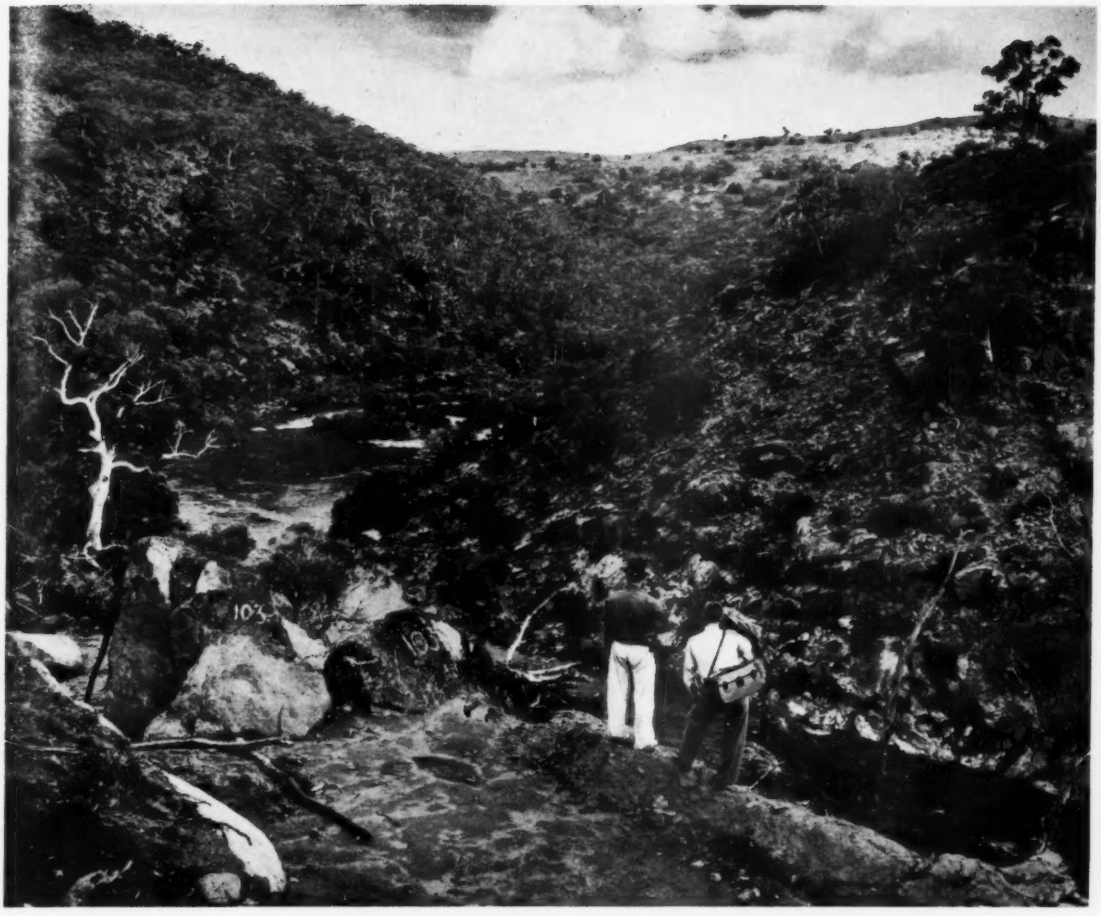


Fig. 21. Proposed dam site on the Snowy River at Jindabyne

vertical shaft similar to that at Island Bend and pass through turbines before entering the main tunnel. The third power station (M6) will be built where the tunnel breaks surface at Bogong Creek and the fourth and largest (M7) will be in the tunnel near its outlet at Swampy Plains River.

It will be seen that whereas the first two of these power stations develop power from waters led into the tunnel from the rivers above, in the case of the other two power stations the full flow of the tunnel is used.

The existing Hume weir across the Upper Murray will be raised to increase its present capacity of 1¼ million acre-feet to 2½ million acre-feet to form the main irrigation storage for the Murray valley.

In the second section power will be developed from the upper reaches of the Snowy river. A dam will be built on Spencer's Creek, a tributary of the Upper Snowy not far from its source, and the water from this reservoir passed to the shaft intake at Island Bend through three power stations (M1A, M1B and M2) situated at Guthega River, Munyang River, and Island Bend, where dams will be thrown across the Snowy. The first and third stations will be underground, but the second will be on the mountain side and fed by tunnel and penstock.

The third section will make use of Windy Creek

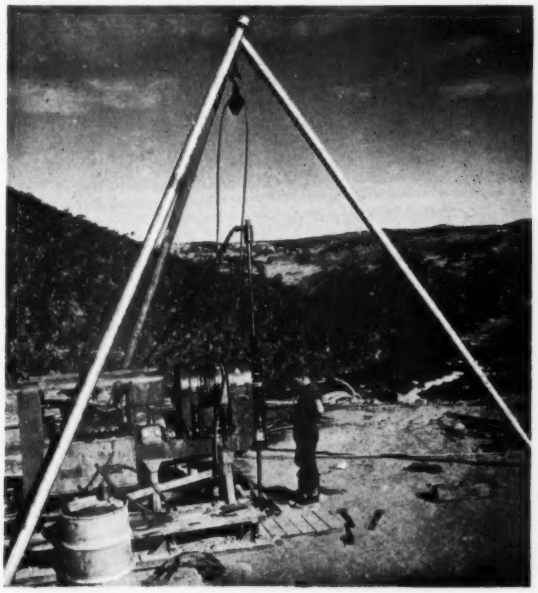


Fig. 22. Diamond drilling at Jindabyne

and Geehi River, the water being passed through two underground power stations (M4 and M5H) before being dropped into the tunnel.

Ultimately the demand storage will be held to the fullest possible extent at Spencer's Creek, but in the earlier stages the main storage will be held at Jindabyne.

Snowy-Tumut Development

The Snowy-Tumut development, a section and plan of which appear in Fig. 20, may also be considered in three sections. The main section consists of diverting the Eucumbene at Adaminaby to the Tumut valley. It involves the construction of a high dam near Adaminaby where the main demand storage will be held, and an 18-mile diversion tunnel, over 20 ft. in diameter, to a power station (T1) on the Upper Tumut River downstream of Tumut Pond. Water from this station will be returned to the Tumut, impounded, and passed through a 9-mile tunnel to a second underground station (T2), returning to the river at Lob's Hole reservoir. A third station (T5) situated at the foot of the Lob's Hole dam, will discharge to an aqueduct, 12 miles long, from the end of which a pipeline will drop the water to a fourth station (T6) located at the inlet to Blowering reservoir. This reservoir will form the main storage for irrigation in the Murrumbidgee valley, and a fifth power station (T7), at the foot of the dam, will be used only when water is released for irrigation purposes.

The diversion of the Upper Murrumbidgee to the Tumut forms the second section of this scheme. This involves the construction of a dam at Tantangara and 8½ miles of tunnel to Yarrangobilly Creek, where a power station (T3) will be located. Below this a small dam will divert the water through a second tunnel about 5 miles long to a station (T4) situated above Lob's Hole, where it will join the Tumut.

Thirdly, the Tooma waters will be diverted to the Tumut by a large aqueduct more than 50 miles long and a 4-mile tunnel. The diverted water will be discharged into Tumut Pond and will therefore pass through the five stations in the Tumut system.

In view of the size and complexity of the Snowy Mountains scheme, the main statistical data have been assembled in Table VIII for easy reference.

TABLE VIII
DAMS AND STORAGE*

Developments	Dam	Height	Storage Capacity
		ft.	acre feet
Snowy-Murray	Jindabyne	260	1,200,000
	Spencer's Creek	90	30,000
	Upper Murray	Not yet determined	Not less than 1,000,000
Snowy-Tumut	Adaminaby	385	3,500,000
	Tumut Pond	280	43,500
	Tantangara	150	300,000
	Lob's Hole	180	50,000
	Blowering	250	800,000
Total Storage			6,923,500

*These figures are tentative only and are subject to alterations as detailed investigations proceed.

TUNNELS

Snowy-Murray	
Jindabyne-Geehi River	17½ miles
Geehi-Bogong Creek	4½ miles
Bogong Creek to Swampy Plains River ...	7 miles
Spencer's Creek to Island Bend	10 miles
Snowy-Tumut	
Adaminaby to Tumut Pond	15½ miles
Tumut Pond to Power Stations 1 and 2 on Upper Tumut (2 tunnels)	12½ miles
Tooma River to Tumut Pond	5 miles
Tantangara Reservoir to Yarrangobilly Valley	8½ miles
Yarrangobilly Valley to Lob's Hole	5 miles
Total Length of Tunnel	85½ miles

POWER STATIONS

Snowy-Murray (9 stations)	
Spencer's Creek to Island Bend—3 stations	180,000 kW
Island Bend shaft	166,000 kW
Windy Creek	47,000 kW
Geehi Pond	66,000 kW
Geehi Shaft	21,000 kW
Bogong Creek	290,000 kW
Swampy Plains	910,000 kW
Total ...	1,680,000 kW
Snowy-Tumut (7 stations)	
Upper Tumut River Stations Nos. 1 & 2 ...	660,000 kW
Tantangara to Lob's Hole—2 stations ...	265,000 kW
Lob's Hole Dam Power Station	115,000 kW
Tumut Canal Power Station	90,000 kW
Blowering Dam Power Station	50,000 kW
Total ...	1,180,000 kW
Total Installed Capacity ..	2,860,000 kW
Total Firm Power	2,620,000 kW

(Note.—Various amendments following detailed investigations now bring the total estimated firm power to approximately 3,000,000 kW).

AQUEDUCTS

Approximately 490 miles of aqueducts will be built, mostly at high elevations, to pick up the mountain streams, and lead them to tunnels and storages.

WATER AVAILABLE FOR IRRIGATION BY DIVERSION AND REGULATION

Diversion Quantities	
Snowy at Jindabyne to Murray ...	730,000 acre ft. p.a.
Eucumbene to Tumut	235,000 acre ft. p.a.
Tooma to Tumut	330,000 acre ft. p.a.
Murrumbidgee to Tumut	300,000 acre ft. p.a.
Total ...	1,595,000 acre ft. p.a.
Gain to Murray by Diversion and Regulation	
Directly diverted from Snowy ...	400,000 acre ft. p.a.
Due to regulation	540,000 acre ft. p.a.
Total ...	940,000 acre ft. p.a.
Gain to Murrumbidgee by Diversion and Regulation	
Directly diverted from Snowy ...	565,000 acre ft. p.a.
Due to regulation	835,000 acre ft. p.a.
Total ...	1,400,000 acre ft. p.a.
Total Gain to Murray and Murrumbidgee	2,340,000 acre ft. p.a.

SHARING OF WATER BY NEW SOUTH WALES AND VICTORIA

	N.S.W.	Victoria	Totals
Murrumbidgee River	1,400,000	—	1,400,000 ac. ft. p.a.
Murray River	570,000	370,000	940,000 ac. ft. p.a.
Totals	1,970,000	370,000	2,340,000 ac. ft. p.a.

(To be continued)

Overflow-Type Surge Tanks

Prof. L. Escande presents a rapid approximate method of analysis which avoids recourse to the normal graphical solution and gives closely comparable results

WHEN the load is rejected from a hydro-electric station provided with an overflow-type surge chamber, the inertia of the water flowing in the supply tunnel raises the water level in the chamber and causes an overflow, and it is important to the designer to determine the extent of this overflow. For one reason, the overflow is usually returned to the river bed through permanent works (such as a shaft spillway, a steep open conduit, a stilling pool, etc.) the capacity of which depends essentially on the overflow discharge and total time of spilling. Secondly, the total volume of overflow is of interest because it represents a loss of usable water, that is to say, a loss of available power. The determination of the total volume of the overflow may also influence the design of the surge chamber itself. For instance, the overflow water is often recovered in a reservoir connected to the headworks through a conduit of such restricted cross section that it can only empty very slowly.

The general equations governing surge-tank oscillations cannot be resolved analytically beyond the point at which overflow commences, and recourse has to be made to graphical or semi-graphical methods, or even to step-by-step calculations. Such processes yield precise results but they are relatively lengthy and tedious to use.

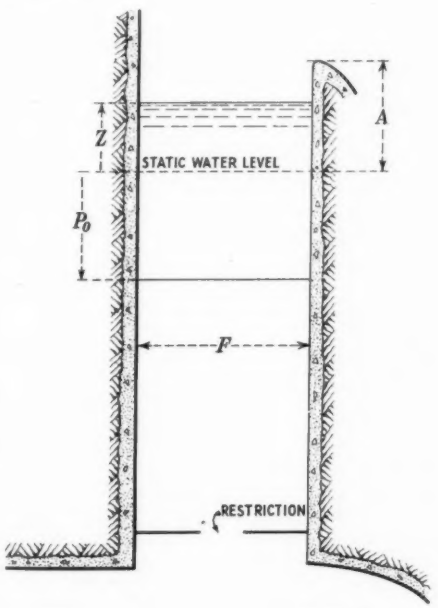


Fig. 1. Diagram of overflow-type surge tank

Having had occasion to calculate many overflow-type surge chambers, the author has been led to try out an analytical method of calculation based on a simplified hypothesis, and to compare its results with those obtained by the normal graphical method. The comparison shows that this analytical method gives remarkably close results in the cases examined, and its adoption would appear to be justified.

Phase prior to Overflow

Z and A respectively (Fig. 1) represent the height of the water surface at a time t, and that of the sill of the overflow weir, above static water level. Overflow does not occur until Z exceeds A. Up to that point the oscillation is that obtaining in a non-overflow-type chamber, and is analysed in accordance with classical theory.

Let us take, for instance, the case of the instantaneous shut-off of the maximum continuous discharge Q_0 through the turbine. The fundamental equation for oscillations within normal limits, taking into account, for wider applicability, the case of a chamber having a restricted orifice, is as follows:—

$$v^2 = \frac{1}{2(p_0 + r_0)^2}\left\{1 - 2(p_0 + r_0)z - [1 - 2(p_0 + r_0) r_0]\, e^{-2(p_0+r_0)(p_0+z)}\right\}$$

where:—

L, f = length and cross-sectional area of the supply conduit

F = horizontal section, supposed to be constant, of the surge chamber

W = velocity in the supply conduit, taken as positive when the flow is towards the surge chamber

V = upward velocity of the water surface in the surge chamber

W_0, V_0 = values of W and V defined by the relationships: $Q_0 = fW_0 = FV_0$

$T = 2\pi\sqrt{\frac{LF}{gf}}$ = period of oscillations in the absence of overflow

$Z_* = W_0\sqrt{\frac{Lf}{gF}}$ = amplitude of oscillations in the absence of overflow, restriction, or any loss of head in the supply conduit

P, P_0 = head losses in the supply conduit for velocities W and W_0 respectively

R, R_0 = head losses in the restriction: R at time t_1 and R_0 when the discharge Q_0 is passing through the restriction

$$v = \frac{V}{V_0}, \qquad w = \frac{W}{W_0}, z = \frac{Z}{Z_*},$$

$$p = \frac{P_0}{Z_*}, \qquad r_0 = \frac{R_0}{Z_*}, p = \frac{P}{Z_*} = p_0 w^2$$

$$r = \frac{R}{Z_*} = r_0 v^2, t' = \frac{t}{T}, a = \frac{A}{Z_*}$$

The water surface reaches the sill of the overflow weir when Z becomes equal to A; the corresponding value w_1 of w, equal to the value v_1 of the quantity v derived above for the instantaneous shut-off of the turbine discharge, is given by the following equation:

$$w_1^2 = v_1^2 = \frac{1}{2(p_0 + r_0^2)} \left\{ 1 - 2\ (p_0 + r_0)\ a - [1 - 2\ (p_0 + r_0)\ r_0]\ e^{-2\ (p_0 + r_0)\ (p_0 + a)} \right\}$$

from which the following values of the velocity in the supply conduit, and of the flow into the surge chamber at the moment when overflow commences, may be deduced:—

$$W_1 = w_1\ W_0 \text{ and } Q_1 = f\ W_1 = w_1\ Q_0$$

First Assumption

When Z becomes greater than A overflow commences from a layer of water which first rapidly increases in depth, then reaches a maximum, and finally shrinks to zero. In our calculation we assume that the sill of the overflow weir is infinitely wide, and that therefore the head producing the overflow remains practically nil. In other words, we regard Z as remaining at the value A during the whole period of the overflow, and accordingly we do not take account of the positive or negative accumulations within the chamber.

The errors resulting from this assumption are definitely in the direction of safety; in effect, to restrain the movement of the water in the supply conduit we apply, throughout the period of the overflow, a theoretical counter-pressure A which is less than the actual counter-pressure $A + h$, where h is the head above the overflow sill.

Overflow Analysis

On the basis of the foregoing assumption the general equations become:—

$$\frac{L}{g}\ \frac{dW}{dt} + A + P + R = 0,$$

$$P = \frac{P_0}{W_0^2}\ W^2,\ R = \frac{R_0}{W_0^2}\ W^2,\ Q_d = f\ W$$

where Q_d denotes the rate of overflow at the moment t. If we write:—

$$\frac{P_0 + R_0}{W_0^2} = \lambda$$

we get

$$\frac{L}{g}\ \frac{dW}{dt} + A + \lambda\ W^2 = 0$$

Integrating with respect to t, and taking $t = 0$ as the moment when overflow commences:—

$$t = \frac{L}{g\sqrt{A\lambda}} \left[\tan^{-1}\ W_1 \sqrt{\frac{\lambda}{A}} - \tan^{-1}\ W \sqrt{\frac{\lambda}{A}} \right] \quad (1)$$

from which we deduce:—

$$\tan^{-1}\ W \sqrt{\frac{\lambda}{A}} = \tan^{-1}\ W_1 \sqrt{\frac{\lambda}{A}} - \frac{g\sqrt{A\lambda}}{L}\ t,$$

and the value of the overflow discharge is:—

$$Q_d = f\ W = f \sqrt{\frac{A}{\lambda}} \cdot \frac{W_1 \sqrt{\frac{\lambda}{A}} - \tan\left(\frac{g\sqrt{A\lambda}}{L}\ t\right)}{1 + W_1 \sqrt{\frac{\lambda}{A}} \cdot \tan\left(\frac{g\sqrt{A\lambda}}{L}\ t\right)} \quad (2)$$

In accordance with the basic assumption, this discharge is evidently a maximum and equal to $Q_1 = fW_1$ when $t = 0$ and ceases at a moment t_2 when $W = 0$:—

$$t_2 = \frac{L}{g\sqrt{A\lambda}}\ \tan^{-1}\ W_1 \sqrt{\frac{\lambda}{A}} \quad (3)$$

The total volume Ω of spillage is:—

$$\Omega = \int_0^{t2} Q_d\ dt \quad (4)$$

where Q_d is given by equation (2) above.
If we write:—

$$u = \tan\left(\frac{g\sqrt{A\lambda}}{L}\ t\right)$$

which gives:—

$$dt = \frac{g\sqrt{A\lambda}}{L}\ \frac{du}{1 + u^2}$$

equation (4) becomes:—

$$\Omega = \frac{fL}{g\lambda} \int_0^{t2} \frac{\left(W_1 \sqrt{\frac{\lambda}{A}} - u\right) du}{\left(1 + W_1 \sqrt{\frac{\lambda}{A}}\ u\right)(1 + u^2)} \quad (5)$$

The integration of this fractional expression, carried out by the usual method of integration by parts, finally gives the volume sought:—

$$\Omega = \frac{W_0^2}{2g} \cdot \frac{Lf}{P_0 + R_0} \cdot \log\left[1 + \frac{P_0 + R_0}{A}\ \frac{W_1^2}{W_0^2}\right] \quad (6)$$

To sum up:—
The rate of overflow Q_d is given by equation (2)
The maximum value is $Q_1 = fW_1$
The total time of spilling t_2 is given by equation (3)
The total volume of spillage Ω is given by equation (6)

Comparison with Graphical Method

The author has compared the results obtained by the foregoing method with those given by the graphical method in the cases of the surge tanks serving two power stations in Yugoslavia—Vela IV and Jajce II, the particulars of which are given in Table I.

Figs. 2 and 3 give the graphical constructions relating to the two chambers investigated, following the method given by Mm. Bouvard and Molbert in *La Houille Blanche*, September-October 1950. Table II compares the two methods of calculation as regards maximum flow in cu.m. per sec., total time of

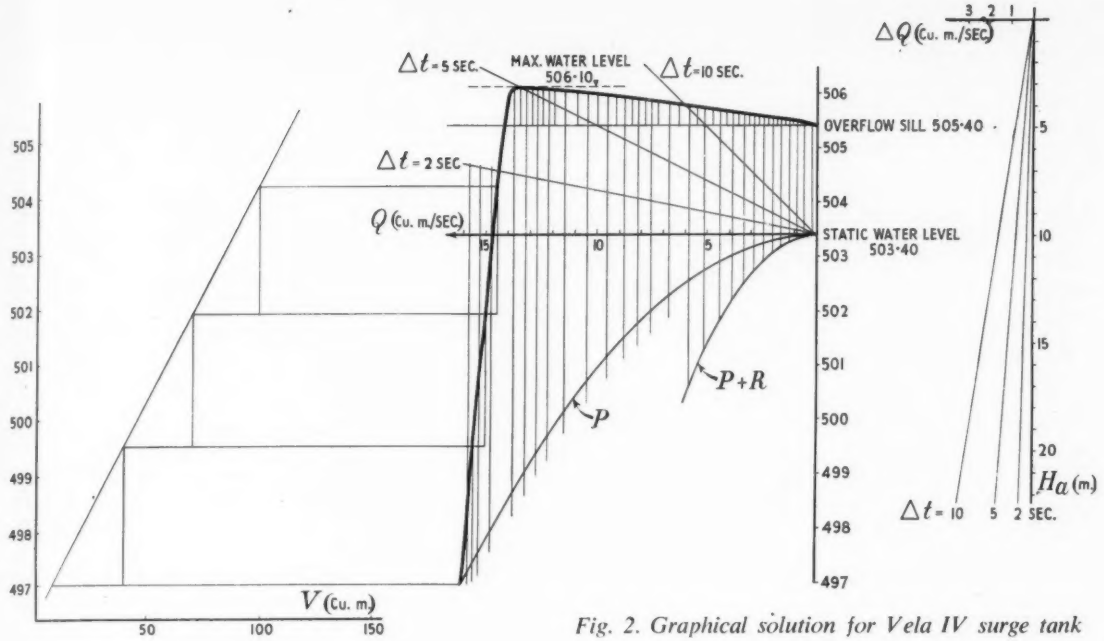


Fig. 2. Graphical solution for Vela IV surge tank

Table I

		Vela IV	Jajce II
P_0	cu. m. per sec.	16	76·5
f	sq. m.	5·92	23·76
L	m.	3,700	2,804
F	sq. m.	12·5	190
A	m.	2	2·70
P_0	m.	6·40	4·50
R_0	m.	15	16·35

spilling in seconds, and total volume of spillage in cu.m. It can be seen that the errors do not reach 10 per cent. and that they are in the direction of safety.

Table II

Station		Analytical method	Graphical method	Relative error%
Vela IV	Maximum flow	14·10	13·68	3
	Total time of spilling	192	179	7
	Total volume of spilling	853	796	6·9
Jajce II	Maximum flow	51·6	47	9·3
	Total time of spilling	131	125	4·7
	Total volume of spillage	2,545	2,360	7·5

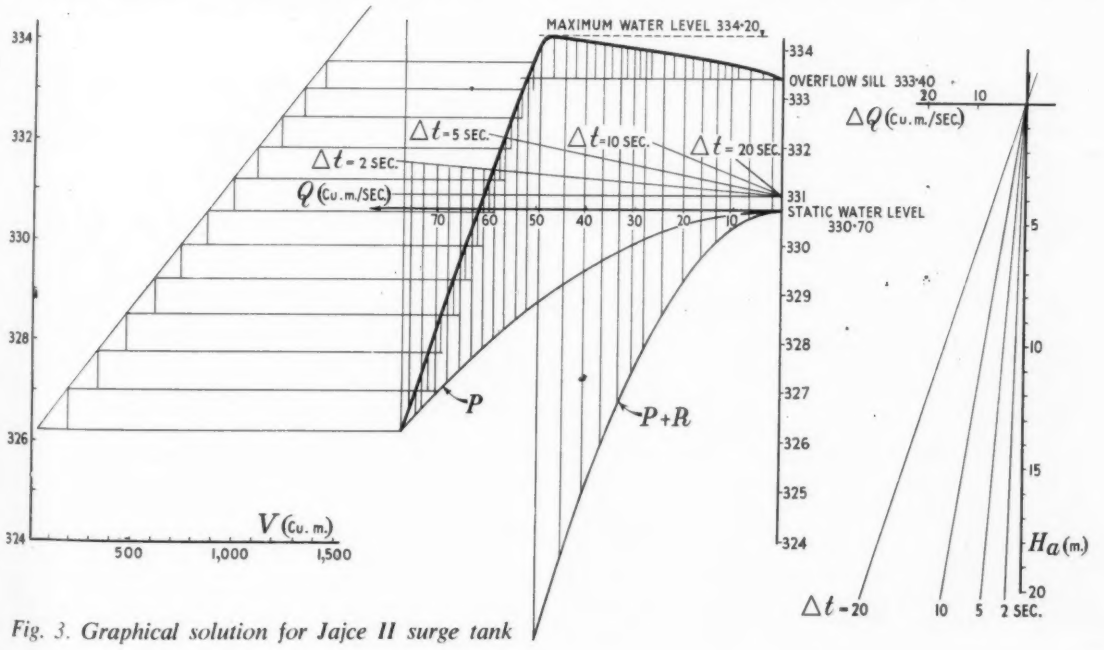


Fig. 3. Graphical solution for Jajce II surge tank

Second Assumption

The approximation obtained by the analytical method set out above is sufficient in the majority of cases, particularly if account is taken of the fact that the errors lie in the direction of safety. We are about to show, however, that a considerably higher standard of accuracy can be obtained. In the preceding general formulae we will replace A by the expression:—

$$A + 0{\cdot}5\, h_1$$

as the mean value of the counter-pressure during the overflow, where h_1 denotes the head necessary above the sill for a flow of $Q_1 = f W_1$. h_1 is easy to calculate from the characteristics of the overflow weir.

On this assumption:—

The maximum discharge is always $Q_1 = f W_1$

The total time of spilling is given by:—

$$t_2 = \frac{L}{g \sqrt{\lambda\,(A + 0{\cdot}5\, h_1)}} \tan^{-1} W_1 \sqrt{\frac{\lambda}{A + 0{\cdot}5\, h_1}}$$

The total volume of spillage is given by:—

$$\Omega = \frac{{W_0}^2}{2\,g} \cdot \frac{Lf}{P_0 + R_0} \cdot \log \left[1 + \frac{P_0 + R_0}{A + 0{\cdot}5\, h_1} \frac{{W_1}^2}{{W_0}^2} \right]$$

Comparison of Analytical Method embodying the Second Approximation with the Graphical Method

If we establish a comparison similar to that already made for the Vela IV and Jajce II surge tanks but using the analytical method embodying the second approximation that we have just indicated, we obtain the results given in Table III. It can be seen that the errors are extremely small, and in particular those relating to the total volume of spillage, which is the most important factor in practice, are practically negligible.

Table III

Station		Analytical method	Graphical method	Relative error
Vela IV	Maximum flow	14·10	13·68	3
	Total time of spilling	174	179	−2·84
	Total volume of spillage	796	796	0
Jajce II	Maximum flow	51·6	47	9·3
	Total time of spilling	120	125	−4·08
	Total volume of spillage	2,360	2,360	0

Conclusions

The analytical method presented in this article gives formulae capable of yielding, within a high standard of accuracy, all the data required to establish the design of an overflow-type surge tank without recourse being necessary to the graphical methods normally employed.

ACKNOWLEDGMENT. This article originally appeared in French in *Bulletin de la Société Française des Mécaniciens*, No. 5, June 1952.

Book Reviews

The Structure and Capacity of Australian Manufacturing Industries. Division of Industrial Development, Department of Natural Development, Australia. 13 × 8¼ × 1½ in. 528 pp. Angus and Robertson, 89-95 Castlereagh Street, Sydney, and 48 Bloomsbury Street, London, W.C.1. Price £3 net.

This publication provides an exhaustive analysis of Australia's manufacturing economy. It carries 17 chapters, each of which is devoted to a particular industry or related group of industries, and each chapter is divided into three parts dealing respectively with the structure of established manufacturing industries, an outline of capacity of manufacturing industries, and basic statistics. Of particular interest to hydro-electric engineers is the first chapter, entitled "Fuels, Lubricants, Light, Power," in which the "set-up" of Australian power supply, from both thermal and hydraulic sources, is concisely but fully described.

St. Lawrence & South Hudson Bay Drainage. Water Resources Paper No. 103 of the Department of Resources and Development, Canada. Issued by the Minister of Resources and Development, Ottawa, Canada. 1952. 430 pp. French and English text. Price $3.00.

This report, which covers the climatic years 1947-48 and 1948-49, is essentially one of a series designed to cover the St. Lawrence and Southern Hudson Bay Drainage Division of Canada and contains stream flow and water-level data at a number of selected points. For a number of the rivers the discharge records, published in previous reports, cover a considerable period of years. At the gauging stations at which systematic records have been secured the following data are given: (1) Location and description of the station, (2) Table of monthly discharge and run off, (3) Table of daily discharge. For each station mention is made of the type of gauge in use, the extent of the drainage area, method of metering, records available, extremes of stage and other relevant information.

Canadian Water Resources Paper No. 106. Water Resources Division, Department of Resources and Development, Ottawa 4, Ontario, Canada. Price $3.00, remittance to be in favour of the Receiver General of Canada.

Volume 106 of the Water Resources Papers, Surface Water Supply of Canada, has been published and is now available for distribution. This report contains run-off data for the climatic years 1946-47 and 1947-48 for the Pacific Drainage division which covers the larger parts of the Province of British Columbia and Yukon Territory. The data presented are the results, for the period October 1, 1946, to September 30, 1948, of the hydrometric operations which were carried out in this drainage in large part by the Water Resources Division, although operations were facilitated by active co-operation received from the Water Rights Branch of the British Columbia Department of Lands and Forests and a number of other governmental and private agencies.

This report includes a short description of the organisation and scope of operations, an explanation of the method of tabulation, and 370 pages of streamflow and water-level data for a number of rivers, streams, and lakes in British Columbia and Yukon. The appendix contains a reference list of hydrometric records for this drainage division, a list of available Water Resources Papers, and an index to the current issue.

A New Type of Run-of-River Power Station

Numerous technical advantages are claimed for a design of river station in which the generating sets are individually incorporated in piers between successive lengths of spillway, as opposed to the conventional arrangement of a station block succeeded by a spillway block.

By ALEXANDER B. SCHULZ
CONSULTING ENGINEER, BERLIN-SIEMENSTADT

THE ultimate aim in the development of the run-of-river type of power station is simplicity and economy of design, negligible head losses, high efficiency, ability to cope with detritus and ice, robustness, and of such an exterior that it harmonises with any river landscape.

To attain this aim by any further improvement in the conventional type of station with its continuous weir and single power house—in use almost exclusively all over the world and developed from the diversion-canal type of station—is impossible in principle for the following reasons:

(1) Almost no structural member of this type of station can be further considerably simplified and still less be entirely omitted.

(2) It is impossible to avoid the loss of energy, about 1·5 per cent., which results from the diagonal flow across the river to the power station, combined with the frontal disposition of the turbine inlets and spirals.

(3) It is impossible to distribute the floodwater and silt carried along with it uniformly along the whole breadth of the tailwater and thus to solve such problems as the dissipation of the floodwater energy or the utilisation of its kinetic energy in a simple and economic manner.

(4) With the conventional type of station serious complications are created by detritus and ice.

(5) It is very difficult efficaciously to protect the machines and mechanisms, the most valuable and sensitive parts of the plant, concentrated within a narrow compass, against damage inflicted by war or sabotage.

(6) It is often difficult to arrange a big building block to harmonise with a river landscape.

Indeed, it may be said that for about 20 years past the development of this type has come to a standstill. The reason for this is that the turbine components comprising the inlets, spirals and draught tubes are necessarily arranged in the basement of a single build-

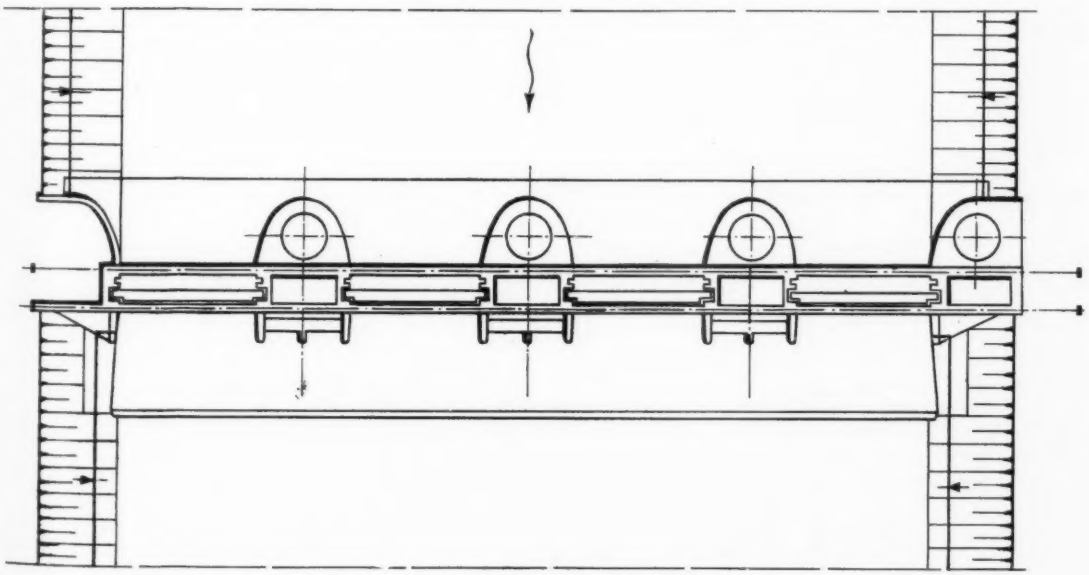


Fig. 1. Plan of proposed layout for run-of-river station

ing. This interconnection automatically creates the necessity for a continuous weir alongside the power station, thus dividing the stream into a power flow and a surplus flow. Such a subdivision, which is, of course, inherently reasonable in the case of diversion-canal stations, is not in the least logical with river power stations where the diversion of the flow in the river bed creates all the fundamental disadvantages of the diversion-canal type of station.

If, however, separation of weir and power house is avoided, that is, if the turbo-generator sets and weir openings are arranged alternately along the whole breadth of the river, further possibilities of development immediately present themselves.

Previous attempts to effect this[1–7] have not resulted in a solution qualified to replace the conventional arrangement. The author's suggestion, illustrated in Figs. 1—4 and fully described in what follows, is a new attempt to give the river power station its logical shape of a "flow machine" composed of several detached generating units, and thus bring it within approachable distance of the final aim of development already defined.

For this new type of station the piers not only house the generating units and ancillary equipment but also serve as supports for the large weir gates required. The total length of the structure, i.e. of the weir and power station, is thus reduced by the total breadth of the piers that would have been necessary for a continuous weir, and the useful length of the distributed weir is nearly twice as effective. The breadth of the piers contradicts the classical rules of weir construction, but these rules are founded on a two-dimensional configuration of flow that does not occur in the ordinary course of nature; consequently the classical theory proves insufficient as soon as substantially three-dimensional flow arises in the tailwater of the weir because of careless handling or damaged gates.* The new suggestion therefore deliberately aims at obtaining harmless three-dimensional flow in both the head and the tailwater.

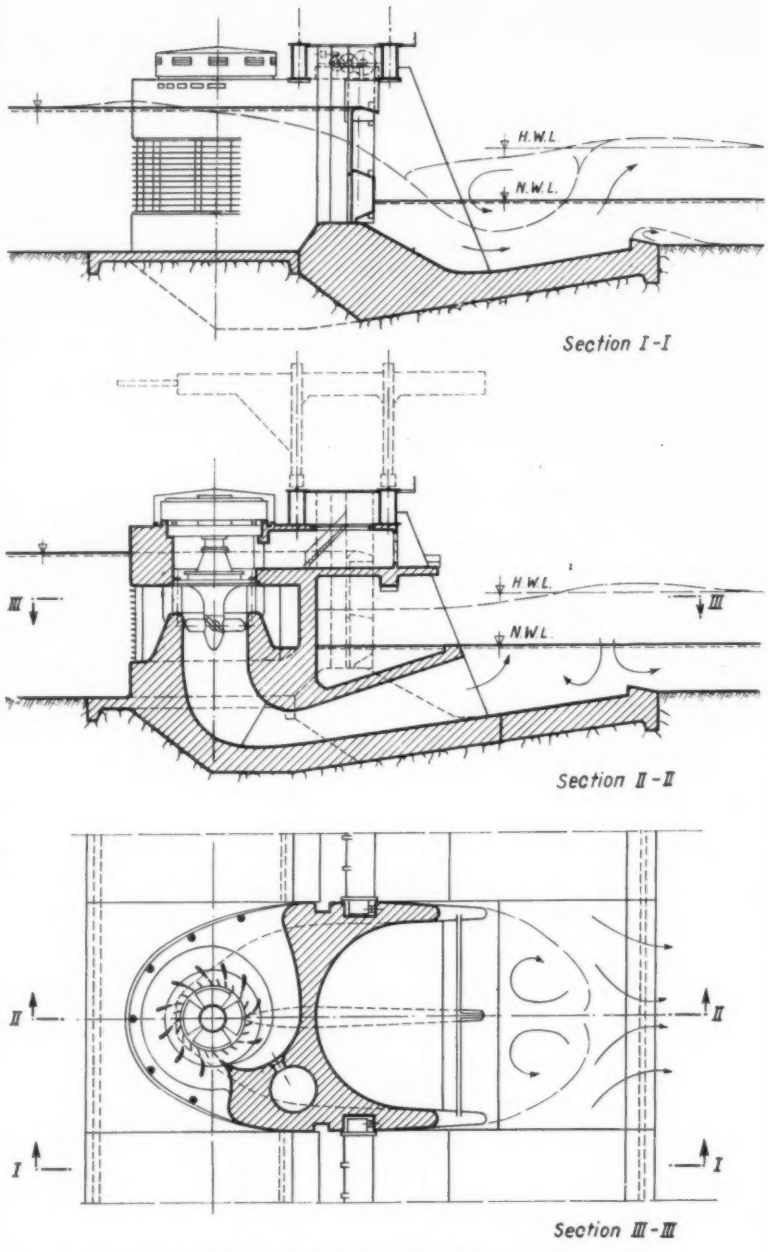


Fig. 2. Sections through spillway and power unit

In relation to the turbine axis, the weir gates are placed as far as possible downstream; thus the turbines are wholly in the headwater and are free from losses due to vortex action at the entry to the spillway. The simple and economic manner of execution is shown by Fig. 2. The length of the power-station block is reduced to two-thirds of that required for the centralised station while the piers occupy about half the width normally required. The intake opening for the turbines has double the effective width and therefore only half the height of the frontal inlets. It

* A recent example is afforded by the weir at Birsfelden on the Rhine where enormous stone rip-raps have had to be provided in order to prevent scouring action by vertical side vortices.

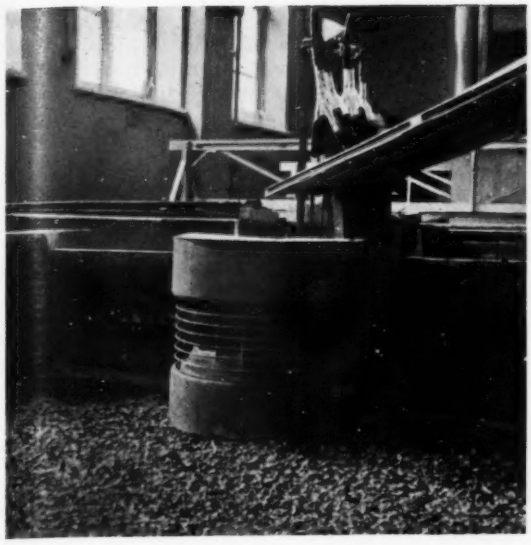


Fig. 3. Model of run-of-river unit

can thus, of course, be situated at the mid-depth of the flow and hence in the clearest stratum of water, consequently requiring no further protection from drift ice and detritus. In order to protect the turbines from floating matter the inlet is provided with a grille consisting of horizontal bars curved to follow the streamline shape of the pier head. The grille is cleaned by means of a mechanically driven rake which pushes any debris over the weir gates whence it can be diverted into the tailwater. In order to empty the turbine recess, suitably constructed steel-sheet piles or rubber mattings are applied over the grille, which is designed to withstand the full pressure of water.

The stilling-pool basin runs along the whole width of the dam structure, and the floor slopes up from the lowermost level of the draught tubes to the level of the river bed, ending in a low sill.

The box girders between the piers, with the crane gantry, serve as a connecting bridge for the staff and also carry the conduits, conductor rails, cables, etc. Where ice conditions permit, a floating crane assembly can be used and only a light box girder is necessary.

Model tests on this new type of station were carried out by Chief Engineer Eicke[11] in the years 1950-52 at the Institute of Hydraulic Engineering, directed by Prof. Dr.-Ing. H. Press at the Berlin Technical University, and yielded the following results:

The water flow round the pier head and the feed stream to the turbine were found to be correct with all possible positions of the weir gates. Floating matter did not cling to the sides of the grille but was carried away by the stream when the weir was open. Floating matter clinging to the face of the grille could also be removed without using the rake, simply by generating an asymmetric flow round the pier.

Owing to the symmetrical flow round the pier a powerful ejector effect is imposed on the draught tubes by the excess water flowing over the spillways. Increases of effective head up to about 50 per cent. and increases in the volume of water passing the turbine up to 25 per cent. have been measured, resulting in a power increase of about 60 per cent. This ejector effect does not function if the water flows on one side of the pier only.

The jet effect in the weir openings causes a spread downstream of the piers at an angle of about 45° and the surplus energy to be delivered to the turbines, the standing wave so weakening the energy of flow that the unprotected river bed is not subjected to erosion.

On the strength of these results it is possible to state that this new type of station has already justified itself from static and dynamic considerations, and may well be supposed to reach even greater efficiency when further improvements, based on working experience with practical plants, have been made.

In the case of low heads the turbine chamber can be shaped to act as a syphon, and with considerable heads the possibility is opened up of extending the spillway over the piers containing the power units. In rivers with very heavy ice flows, as for instance in Canada, special ice breakers may be necessary in front of the piers if the depth of the headwater is small and the velocity of flow considerable in conse-

(Continued on page 184)

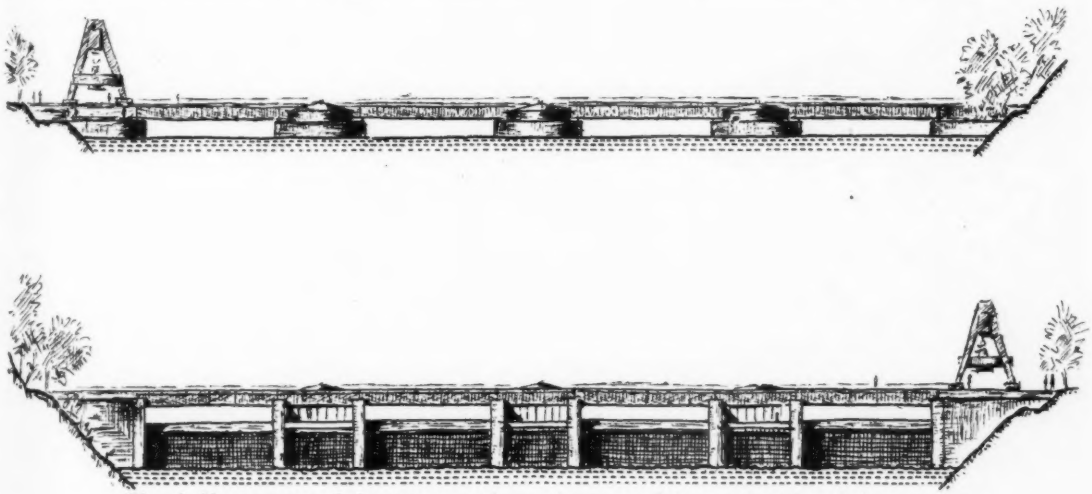


Fig. 4. Upstream and downstream views of proposed layout for run-of-river station

Salmon Ladders and Fish Passes

A problem that sometimes assumes considerable importance in the design of dams for hydro-electric works is discussed by a naturalist, Eric Hardy, F.Z.S.

IN the Proceedings of the Institution of Civil Engineers (*1.* 3, May 1952),* in a review of the engineering aspects of hydro-electric developments in Scotland, some brief attention was given to the construction of fish passes as an alternative to fish ladders for getting salmon above the dam which impedes their way to spawning waters, and to screening descending salmon from entering the main tunnel intake. For some time the Salmon and Trout Association and several riparian owners of salmon and sea-trout rivers have been very much concerned about the reluctance of migratory fish to take to altered rivercourses and newly erected dams, and about the long, slow time it has taken many famous salmon waters to recover their salmon stocks after the erection of hydro-electric works. In effect, the influence of the salmon fishery has been brought to bear upon the engineer who in Britain, Norway or North America often finds himself legally obliged to include a salmon ladder or a salmon pass in his works. Even then, the problem is to make the construction successful from the salmon's point of view, with the shortest possible drop in fish-spawning populations in the succeeding years. Four out of six big dams on the Conon River scheme in Cromarty require fish passes.

* See WATER POWER, March 1952, page 92.

Three Types of Construction

There are three principal constructions which may get the salmon over the dam to the upper watershed streams, where it spawns. They should be made before the dams or other obstructions, if possible. A traditional method is a salmon ladder of gradually ascending pools, or a series of shallow steps, over which spillwater maintains a certain flow. An American method (bearing in mind that this term means Canadian also, for we see it very successfully employed on the Fraser River salmon-canning waters) consists of a derrick or crane lifting a colossal bucketload of salmon out of the tailrace pool and hoisting it over the dam. A post-war idea, which seems to have a prominent part to play in this country in the near future, is a hydraulic salmon-lifting shaft, automatically moving fish from a pool at the bottom of the dam to an upper pool at the top, invented by J. H. T. Borland, of Kilmarnock, and of which a successful Irish modification, on the Liffey power station at Leixlip, was described in the Bulletin of the Institution of Civil Engineers of Ireland, April 1951.

The artificial blocking of streams prevents not only spawning salmon, but sometimes, abroad, smelts and other andromadous fish (i.e. those which ascend from the sea to spawn in fresh waters) from reaching higher areas they might otherwise occupy. In Newfoundland,

Fig. 1. A salmon leaping the Shin Falls in Scotland

natural fishways have been blasted out of bedrock around some of these obstructions in experiments to determine whether salmon can use the upper reaches of the streams for reproduction. Experiments have also shown that the overcrowding of smelt eggs such as commonly occurs below obstructions in spawning streams greatly reduces the proportion of eggs which hatch successfully, and the negotiation of the obstruction leads to the occupation of larger spawning areas and a reduction in crowding.

Efforts have been made in some watersheds to make fresh salmon pools and spawning beds for the salmon by blasting pools in the rock-bed of new streams, and by transplanting gravel for spawning beds; but success depends upon how soon the salmon will take to the change, for they are very conservative creatures. On the Rawdon River in Nova Scotia, various turbulators have been constructed to make the current dig salmon pools. An effective one consisted of a deep V of logs, anchored to the banks with the point of the V downstream. The main flow of stream water was thus concentrated at this point, which was somewhat open with a coupling between the logs to obstruct the flow. This produced such strong, vertical currents that an artificial freshet of about two hours' duration made an initial excavation in the bottom to a length of four feet and a depth of one foot. Although such a construction might take years to produce a pool deep enough for salmon to use, its cost is very low. The work can be hastened by manual labour employed to loosen the bottom and remove undermined stones.

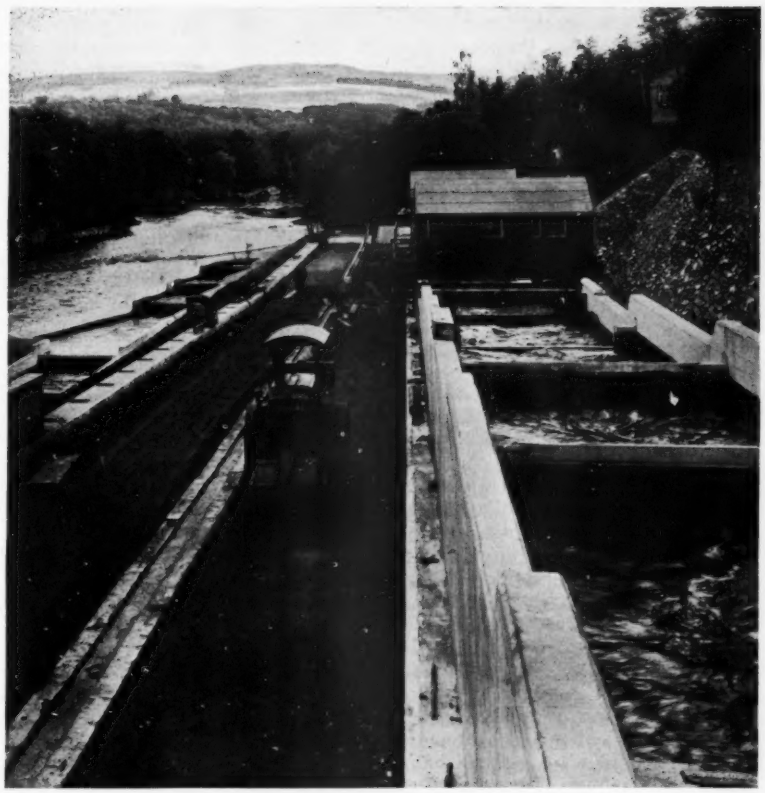


Fig. 2. General view of fish ladder at Pitlochry

The Problem of Descent

In addition to the problem of getting ascending salmon above the dam, there is a lesser problem concerning the safe passage of descending smolts (young sea-going salmon) and kelts (spent fish after spawning). This may govern the design and size of a main tunnel intake and the spacing of a screen which has to exclude descending salmon as well as rubbish. The great size of the Clunie tunnel intake is due to this factor, and screen spacing has been assessed as a minimum of $1\frac{5}{8}$ in. between bars for salmon (2 in. spaces are used in the Spey works of the Lochaber hydro-electric scheme), and $\frac{1}{2}$ in. vertical by 1 in. horizontal for smolts. The velocity of water through the screens at the lowest draw-off level must not exceed the low value of a foot per second if fish are to avoid being sucked against the screen and held there. Electrical screens have not proved to be very satisfactory in repelling the smaller sizes of fish but recent researches have shown that sizable salmon can easily be diverted to the required path by pulsating currents.

Screens (generally $1\frac{5}{8}$ in. spacing) are easier to fix at the tailrace to keep ascending salmon out of the draught tubes, and deflect them to the ladder or lift. Indeed, there may be no need for them where the discharge from the draught tubes is sufficient to deter the salmon. As the main stimulus to ascending salmon is the impact of the water current against their lateral body-lines, or sensitive centres, difficulties might arise where the flow of water down the fish ladder is less than the force of compensation discharge. The salmon would be reluctant to take the weaker current and start leaping to its pools. At the Pitlochry and Clunie (Tummel) fish ladders, which are of the submerged-orifice type, this problem is overcome by compensation-water turbines discharging into the bottom pool of the salmon ladders, so that the ascending salmon are lured there to start on the ladder ascent. The great Clunie tunnel intake has a maximum capacity of 5,100 cusecs compared with 45 cusecs for its salmon ladder. But Fulton has shown (Institution of Civil Engineers) that it is more important to keep down turbulence in the ladder, and Prof. C. M. White designed the submerged-orifice or jet-dispersal type, where instead of the water flowing over the top from one pool-lip to the next, it passes through an opening

See "Controlling Fish," WATER POWER, page 121, April issue, 1953.

at the bottom of the dividing wall into a spoon-shaped depression in the lower pool.

It is important that the way down for the salmon be as close as possible to the maximum draw of the turbine intakes, where the salmon are brought against the screen, and be easy for the salmon to find, because it may prove more difficult to get them down again than to get them up. At the Pitlochry salmon ladder, for instance, 5,600 salmon were counted going up the pass in 1951, but the dam proved more puzzling to the kelt returning, which collected in the dam.

The problem of screening the main tunnel intake against descending salmon has not been satisfactorily met by electrical cathode barriers (a fish is attracted to the anode and repelled from the cathode, particularly if special stimulating currents of certain kinds are used), and typical screens have usually to be enlarged so much that their cleaning presents a problem. A new idea to deflect young salmon from entering intakes, or from passing over spillways, into the fish ladder, has recently been tried out with interesting results by the Pacific Biological Station at Nanaimo, British Columbia, on the Pacific "spring" salmon. In principle it utilises the salmon's dislike of white, turbulent water by floodlighting a barrier of gas bubbles from an underwater pipe.

These experiments were conducted by Brett and MacKinnon in a concrete and brick-lined water canal linking a river with one of the Canadian collieries' power houses. The "gas" consisted of exhaust fumes from a truck on the bank, passed via a rubber hose and through a perforated copper tube sloping downstream from the bank to the centre of the water, at an angle of about 40 deg., so that a wall of bubbles rose from the bed of the canal through the water. Three headlights, mounted on a pole some 15 ft. high on the bank, were adjusted to cast a narrow flashing beam along the rising bubbles. Tests were made with hoop-nets erected to catch salmon on both sides of the canal before and during the experiments. The result showed that two-thirds of the salmon were deflected away from the wall of illuminated bubbles, but on a dark, overcast night five-sixths were deflected. The wall of bubbles alone was not sufficient to deflect the salmon, and the beam of flashing light was the most significant single factor.

Naturally, the engineer will not be entirely satisfied with every third or even every sixth salmon passing his barrier. But these initial experiments were under conditions which made deflection unusually difficult. The rapid flow of the canal at 3·5 ft. per sec. was one factor, and better results might be obtained using submerged lights, and finer bubble holes. The experiments are being repeated in a slower flow of water, and with other species of Pacific salmon of a more schooling nature. In any case, it opens an entirely new method of deflecting salmon from intakes.

The Pool Type of Ladder

The construction of a fish ladder is nowadays no light financial matter. A recent estimate for constructing a stone pool-pass at a 60 ft. high hydro-electric dam was as much as £100,000. An American timber-made pass of the same type would cost much less initially, but would have a much heavier maintenance cost. The concrete hydraulic salmon lift is much cheaper, and cheapest of all is the American "elevator" method practised on the Fraser River in British Columbia, for trapping the salmon in the tail-race of a power station and hoisting them in a giant bucket over the dam and into the reservoir above. A salmon ladder has to be so much longer than the obstacle it negotiates. It takes about 250 ft. with 20 pools (each 10 ft. by 11 ft.) to pass a 20 ft. high barrier, the lower part of the ladder in a gradient of 1 in 10, the upper part 1 in 30. A large resting pool is required on big ladders, and at zigzag bends. There is usually a smaller incline at the upper pools than the first six or seven which may even be 1 in 9 changing about half or a third of the way to 1 in 11·8.

Most salmon ladders are the pool-to-pool type, where the salmon ascends by leaping, from the tail-race pool, a series of stone or cement pools, each about 1 ft. 5 in. to 2 ft. higher in ascending scale and 4 to 6 ft. deep. The higher the dam to be negotiated the longer the ladder, and the more exhausting the journey for the salmon. It may be possible, as in the ladder passing the 15 ft. Irish waterfall at Collooney, to zigzag it with a larger restpool on a hairpin bend, and thus reduce overall length; but only in a few, low obstructions can a roughened channel type of salmon-pass succeed. The ladders must not be inclined too steeply—1 in 10 to 1 in 13 is average.

The original overfall type of ladder, with the water tumbling over the lip of each pool in turn, has been modified so that the water falls through a central notch or lip in the pool wall, or is channelled through a submerged hole 2 ft. in diameter at the bottom of the pool wall into a spoon-shaped depression which dissipates its energy upwards in the next (lower) pool. This maintains a more solid, dark body of water to stimulate the salmon upstream, and through which they can swim more easily than in turbulent white torrents. A faster flow can thus be used in the type with under-water orifice than in the surface-overflow type.

The problem in most designs of salmon ladder is this one of dissipating the energy of the water. It is doubtful if, as the report of the Civil Engineers' Committee on Fish-Passes suggested, that big salmon can leap higher than small ones, but it is unlikely that the average salmon could jump more than six feet in height. It has been shown in Canada that the temporary reluctance of salmon to use a ladder, or the stoppage of a run of fish up one, may not be due to any engineering fault, but to the odour of human hands or feet washed in the water immediately above, and which the salmon detects and resents for several hours, or to cold spring snow-water lowering the temperature.

Water Velocities

The velocity of outflow water at the entrance to the ladder or pass should be as near as possible to the optimum that salmon or sea-trout ascend freely (e.g. 18-36 cubic ft. per sec. or 10-20,000,000 gals. daily), and this of course has a relation with the depth and slope of the steps or channels, the roughness or smoothness of their surfaces, and the deflection of the overfall or submerged jet. The water should flow smooth and black, not white and frothy. Of course, a rough channel of one-in-four slope can maintain, by a series of baffles, a smooth flow of water of low velocity for the fish to ascend; but there is always the problem of flood waters and the gravel or debris they bring down.

The pools may be rectangular or circular, or they may have a staggered inlet notch with baffles projecting upstream from the cross walls so as to compel regurgitation and avoid the piling of flow to one side, which staggering of the notches encourages. With the common overflow type, where the current flows over weir-like crosswalls between the pools, a slow velocity produces a surface flow across each pool with strong, unbroken standing waves. In higher velocity and spate it becomes submerged and sweeps the bottom of each pool, irrespective of the shape (but not the thickness) of the crosswall. The former is the more desirable condition, as it leaves the fish relatively quiet water below the head of each pool where they will collect for their next vault. Central overfall notches aligned on the axis of the ladder, with the drop between pools of not more than 17 in. head difference, are the most successful design of this type for small rivers or flows, using pools 10 to 12 ft. long, 7 to 9 ft. wide and 6 to 7 ft. deep. For big rivers coping with a larger flow the risks of turbulence are kept down by passing the water through a submerged hole or orifice sloped at 20 deg., as already mentioned, using pools 15 to 18 ft. long, 8 to 10 ft. wide and 6 to 7 ft. deep. This method dissipates over 90 per cent. of the inflow energy and gives a smoother flow, which is very useful in floods. It is not much affected by staggering the orifices or by roughening or widening the sides of the pools. It is influenced most by the size of the orifice, which acts like a submerged jet whose inlet is 1·4 times the size of its outlet. A pool 24 ft. by 5 ft. is required for a submerged orifice 2 ft. square (the length of the orifice is twice its width), and a pool half that size for an orifice only a foot wide. A dozen pools have to be built to negotiate only a 9 ft. barrier.

The natural river pool dissipates flow velocity by being deepest at the inflow and sloping upwards to a narrower tail-end; but the use of the submerged hole relies more on the slope of this orifice which is increased if the necessities of space demand shorter pools. The slope of the orifice may be increased to 45° maximum, and permits a reduction of up to 50 per cent. of the length of each pool in the ladder, providing that the spoon-shaped depression receiving the flow slopes upwards to break its velocity. There must be a limit to the shortening of the pools, for in a long climb the salmon wants ample opportunity for resting in some larger pools. Nor should the corners in a zigzag ladder be too sharp. If the pools are too small, and the turbulence too great, injury may occur to the natural slime on the fish's skin, and this sort of injury gives access to furunculosis and other fungus diseases. These resting pools are problems of the much longer salmon ladders of hydro-electric works compared with the small ladders used at ordinary river weirs.

Siting the Entrance

The next most important problem, after velocity control, is siting the mouth or entrance to the ladder. This has to be made in relation to the traditional route of the salmon (they will not usually use one with the entrance too far below the falls), and to the position of any gravel beds or other deflectors after the dam is completed. It might even be possible to construct a salmon-heck—iron bars in the river to permit the flow of water, but to turn the salmon into the tailrace pool. The entrances to the most successful ladders are right under the falls and can readily be found by salmon collected in the pools below the falls. Spring fish will not attempt a rush of highly aerated cold water, white and frothy; but summer fish may do so when the water is warmer, and they form the majority on most rivers—but not all. The chief factor is the quantity and speed of water flowing out of the ladder in relation to that in the river. The velocity is more important here than in the general length of the ladder, and a bypass or special channel can be made to add an extra quantity of water to the approach channel when it is required in spates to keep pace with the increase at the falls. Of course this applies only at the seasons when salmon are running. Some rivers in western Ireland and Scotland are mainly spring rivers, others mainly summer or late season. In others, using aqueducts, spawning beds may lie between dam and power house, and be maintained by compensation water.

In most cases where hydro-electric schemes have been constructed on salmon rivers the run of fish has been affected, and often it has been slow to recover. The fishery is most adversely affected while work is in progress, and only gradually shows signs of recovery. But even in the almost disastrous effect on the Shannon salmon fishery, there was a recovery, slow though it was. The trouble is that salmon take a long time to become accustomed to changes in the river bed, and a new stock has to be built up from those that do accept the ladder. It has been found that a 15,000,000 gallons a day flow causes too much super-aerated water through the sluiced openings for the salmon, and a submerged orifice type of salmon-ladder, with a 2 ft. drop between pools, is best kept between 10—12,000,000 gallons.

The Borland Lift

The type of salmon pass which has attracted most recent support in the Salmon and Trout Association's influential following is the hydraulic shaft-lift, incorporated on the face of the dam structure, and known generally as the Borland lift. A version of this is successfully employed on the Liffey at Leixlip. It does

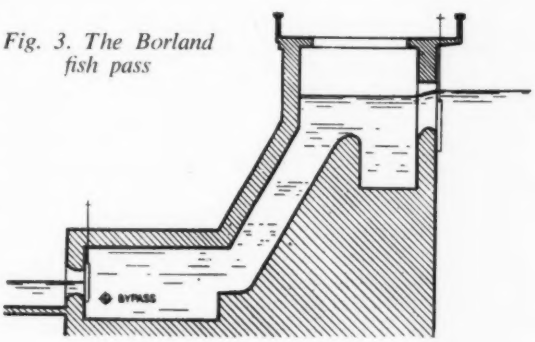


Fig. 3. The Borland fish pass

not exhaust the salmon as when the fish have to vault ten or twenty pools in succession, clearing in effect 40 ft. in order to negotiate something like 15½ ft. by ladder. By flooding a 12 by 6 ft. sloping shaft which connects a cylindrical lower pool, 46 ft. long and 17 ft. in diameter, with an upper pool measuring 19 by 10 ft., the salmon are passed from the downstream to the upstream side of the dam. Not only is it much

cheaper than a long salmon ladder, but it does not waste anything like so much water. This idea is being incorporated into several Scottish hydro-electric schemes now under construction. As the level of water gradually rises up the enclosed shaft from the lower pool, the salmon are taken up with it. The angle of the sloping lift-shaft is set to suit the local construction arrangements.

When not being worked, of course, the shaft will be empty, but the sluices retain about 7 ft. of water in the lower pool, for salmon would not of course leap a 7 ft. wall. In five months it took 2,375 salmon over the 74 ft. high Leixlip dam of the Electricity Supply Board of Ireland. The sluice through which the salmon enter the lower collecting pool is placed just left of the exit of the turbine draught tube, and it has a discharge velocity of 6 ft. per sec. compared with 7 ft. per sec. of the draught tube, which of course may be screened to direct the salmon into the pool. To attract salmon into the bottom pool before a "lift," water is discharged (by control of the upper pool sluice) down the shaft and out of the bottom sluice at 36 cu. ft. per sec. When sufficient salmon have entered, usually after an hour (up to 63 have been lifted at once) the lower sluices are closed and the sloping shaft up the dam face gradually fills, taking about 40 minutes at the rate of 10 cu. ft. per sec. Then, when the top pool is level with the reservoir, a current is maintained through the shaft for an hour and twenty minutes to encourage the salmon to leave for the reservoir. Then the bottom sluice is opened again, and the water is discharged from the shaft. The time taken is not a fixed one, and when big runs of salmon are following a spate, numerous short lifts are most successful. When the runs are smaller, longer spells are sufficient to handle the fish.

An Oerlikon Anniversary

By way of celebrating their 75th anniversary the Oerlikon Engineering Company of Zurich have issued an extremely handsome publication to place on record some of their more outstanding achievements, not only in regard to the wide variety of plant they manufacture but also touching on those intangible elements of initiative, organisation and goodwill which contribute so much to giving the customer what he really requires in this expanding industrial world of ours. It is 25 years since the Oerlikon Company made a similar review of their activities, and interest in the present publication is restricted to the period which has intervened since that date.

In his introduction Dr. Hans Schindler, general manager of the Oerlikon Company, maintains that "economic progress is a consequence of the peaceful co-operation of mankind and that is why we need a common purpose, which, without our always being aware of it, may serve to determine our actions and attitudes."

There may be an immeasurable chasm to bridge before *all* mankind finds itself in such a happy co-operative state but the truth of such an ideal is not to be gainsaid, and it is fitting perhaps that it should be voiced in Switzerland, which affords an example of a nation without a common language yet able to live not only amicably within itself but also with its several neighbours.

The text of the survey takes the form of short articles contributed by the various departmental heads and explaining the developments that have taken place during the last two and a half decades. Thus R. Huber discusses what has been done in the matter of human relations in the firm and Ed. Grüter touches on the working of the purchasing and forwarding department. Other articles deal with organisation and accountancy (W. Daenzer); sales organisation (J. Steinmann); the workshops (J. U. Brunner); research and development (H. Puppikofer); large electrical machines (H. Schulthess); small machines and drives (P. Michaelis); motor control gear (T. Siegfried); transformers (H. Schneider); high-voltage equipment (E. Vogelsanger); special apparatus (A. Bally); service supervision (H. Benninger); rectifiers and electrolysers (B. Storsand); thermal installations (G. Scharffenberg); the Oerlikon gas turbine (Dr. W. Karrer); and electrical traction (C. Bodmer). All these articles are of a technical nature and are not only informative as such, but also serve to indicate the extensive range of activities in which the Oerlikon Company are engaged.

From page 179

quence. In the majority of cases, however, such precautions would not be necessary, for in contradistinction to a continuous weir of the same total clear span, the water and ice approach the weir of a pier plant with only half the velocity that they would in a centralised plant.

In view of the fact that a great body of experience has already been gained in constructing run-of-river projects, the risk of carrying out the suggested new type would be of a negligible order, particularly in consideration of the fact that it would combine a considerable economy in the building masses, a substantial increase in energy generation, a prolongation of the operating time in the event of floods, immunity from troubles due to detritus and ice, a correct dissipation of flood energy, an increase of working reliability, greater immunity from war damage, and finally an exterior that can be made to blend more suitably with any river landscape.

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Book Reviews

The Essentials of Fluid Dynamics. By L. Prandtl. Blackie & Son, Ltd., 66 Chandos Place, London, W.C.2. 452 pp. 35s. net.

Ludwig Prandtl is probably best known as one of the originators of the boundary-layer theory of resistance to fluid flow. He has done equally vital work on other aspects of flow behaviour and is an international authority in the field of fluid mechanics. An eminent and respected teacher, his statement, in English, of a lifetime's experience is therefore of great interest.

"The Essentials of Fluid Dynamics" is the outcome of an accumulation of Professor Prandtl's writings, notably the book entitled "The Physics of Solids and Fluids" (Blackie & Son, 1930). The present work is a translation of the third German edition (1949) of the 1942 book "Abriss der Strömungslehre" ("An Introduction to Fluid Dynamics"), brought up to date and considerably enlarged in the light of wartime advances. The translation has been carried out by Miss W. M. Deans, with Professor H. B. Squires as technical adviser.

The book is intended to be a guide or introduction to the subject, and not a practical handbook. The text is composed of parts in large type forming the basis of the subject, and parts in small type giving more detailed information for the advanced student and the expert. The treatment throughout starts from first principles, yet explores many of the commonly neglected finer points of fluid behaviour. Professor Prandtl's self-avowed object is the awakening of clear, intuitive apprehension. Complex mathematical analysis has been avoided as far as possible, and though frequent mention is made of the practical applications of theory, practical details are kept to a minimum. For example, in the eight pages allotted to it, the section on water turbines, pumps and compressors covers the principles involved, but performance curves or figures are not given.

The book is divided into five chapters, the first three of which are designed in themselves to form an introductory course to the subject. Briefly, they deal with the properties of liquids and gases at rest, the dynamics of ideal frictionless fluids, and, with the introduction of viscosity or fluid friction, the action of real fluids.

The chapter on real fluids, occupying a third of the volume, exemplifies Professor Prandtl's principal object in promoting awareness of the fundamental processes at work in the behaviour of real fluids. It presents a detailed study of the mechanism of turbulence and eddy formation, and deals with such problems as secondary flow in pipes and channels and bearing lubrication. It goes on to discuss aerofoil theory and design. Throughout, copious reference is made to experimental work and results, and the chapter concludes with a section on methods of experiment.

The fourth chapter deals with the dynamics of gases, taking into account compressibility phenomena at both subsonic and supersonic velocities of flow. Shock waves, resistance to projectiles and flow past aerofoils are typical of the problems dealt with, and again a section on experimental techniques, for example windtunnel studies, is included.

The final chapter is headed "Miscellaneous Topics" and deals with subjects which could not conveniently be included in the previous chapters. It covers problems involving more than one state of matter (cavitation, water hammer, hydraulic transport of materials, air-water mixtures,) rotating body flow (effect of the earth's rotation on atmospheric and oceanic currents), flow in heavy stratified fluids (meteorological effects) and convection and heat transfer effects in moving fluids. This chapter, in itself, puts the book outside the ordinary run of textbooks, and makes it an invaluable addition to the shelves of any advanced student of fluid mechanics.

A valuable feature of the book is the abundance of references throughout, augmented by an appendix of recent English and American books and publications prepared under the direction of Professor H. B. Squire.

There is also a bibliography of important textbooks and reference books at the end of the volume. Sufficient numerical values and experimental results are quoted throughout the text to provide a practical appreciation of the theory.

The many illustrations and line diagrams are up to the high standard of the text. The book is attractively printed and easy to read, and, judging by the prevailing high cost of technical books, the price of 35s. for this one is good value.

Reactions between Aggregates and Cement. Part II—Alkali-Aggregate Interaction: British Portland Cements and British Aggregates. National Building Studies Research Paper No. 15. Published by Her Majesty's Stationery Office for the Department of Scientific and Industrial Research. Price 1s. (30 cents U.S.A.) by post 1s. 1½d.

This paper is the second of a series dealing with chemical reactions between aggregates and cement, the first of which was reviewed in our January issue. Serious breakdowns in concrete structures were first attributed to this cause more than ten years ago in America, and since then similar failures have been recorded in many parts of the world. Although no failures caused by cement-aggregate interaction are known to have occurred in this country, the causes and effects of such interaction have been closely studied here. The most serious of these types of chemical reaction is that between siliceous aggregates and the sodium and potassium hydroxides released during the hydration of the cement. The concrete can be cracked by the swelling of the alkali silicate gel formed in this way.

The paper describes measurements of the alkali content of British Portland cements, and gives data on the percentage of alkalis extracted. Some suggested methods of reducing the alkali content of cements are discussed. The second part of the paper surveys the principal British aggregates from the point of view of possible reactivity with such cements. In this country, flints, malmstones and acid or intermediate volcanic types of rock are the most likely sources of reactive material. It is concluded, however, that there is no reason to expect trouble with the normal British aggregates. Where large concrete structures may be involved it would be wise to examine new sources of aggregate for possible reactivity.

Tobique Narrows dam and power station under construction

The Tobique Narrows

Energy from the first unit of the Tobique Narrows Hydro Electric Power Development near Perth, New Brunswick, will shortly be fed into the main circuits of the New Brunswick Electric Power Commission system at Hartland, through a 45-mile steel tower transmission line.

By H. G. COCHRANE, M.E.I.C.

THE Tobique project was first reported on for the Commission by Power Corporation of Canada in 1945. By mid-1950 it was found that rising prices for coal for the Commission's three steam plants, which supplied the bulk of the energy in the Saint John, Moncton, and Fredericton areas, together with the rapidly increasing load on the system, called for immediate development of further hydro power. It was seen that the capacity of the new plant would be fully absorbed by 1954. Authorisation for construction was therefore given in September, 1950.

Though of modest proportions in relation to many of the larger water power developments concurrently being built in Canada, the project embraces a number of unique features. Protection of the salmon fishing interests on the stream was of paramount importance. Reliable records of stream flow were of comparatively short duration. The site was in a deep, narrow gorge where room for the layout was extremely limited. Flooding in the St. John River at the confluence with the Tobique, a mile downstream, would produce tailwater levels higher than the level of the generators,

necessitating a non-buoyant watertight powerhouse superstructure. The nature of the foundation rock appeared soft and not fully satisfactory. Finally, the largest of the four reservoirs was difficult of access and called for methods of construction hitherto seldom used in the Maritime Provinces. A rolled earth fill dam was indicated to save long haul on cement and aggregates.

The Tobique Watershed

The Tobique River has its origin in a network of tributary streams and relatively small lakes lying wholly in the Province of New Brunswick in hilly, heavily timbered country. These streams converge above the town of Plaster Rock, New Brunswick, to form the main body of the Tobique River, which flows in a westerly direction and empties into the St. John River at a point about two miles above the towns of Perth and Andover. A number of rapids occur throughout the length of the Tobique and tributary streams; but no waterfalls of substantial height are present.

Suitable sites for development of storage reservoirs occur mainly on the tributary streams in the upper reaches of the watershed, whereas the most favourable site for initial power development is located on the main river less than one mile from its confluence with the St. John River.

The river valley from Perth to Plaster Rock is served by railroad (which follows the river bank) and by provincial highways. Access to storage-reservoir sites is by logging roads branching from the highways.

Stream flow data for the Tobique River is available for the period 1921 to 1932 from readings taken at the Arthurette gauging station operated by the Canadian Government Department of Resources and Development. These data were compared with run-off figures available for the adjacent Nipisiquit and Shogomoc drainage basins covering a longer period of time, to establish that the above period could be accepted as representative. Adjustments were then made on a proportional basis for the drainage areas involved, and the resulting figures used in the compilation of the required hydraulic data.

The combined spilling capacity of sluices and units at the power plant is approximately 82,000 cusec. at normal high pond level. Freeboard and protective works will permit a further rise in pond level of five feet; and thereby increase the spilling capacity to 102,000 cusec. without damage to property. This figure corresponds to 60 cusec. per square mile of drainage area.

Combined storage capacity of the four reservoirs is 187,500 acre feet, which would correspond to a spring run-off of 15·1 in. from the 232 square mile drainage area. However, capacities of individual reservoirs vary from 14·3 to 17·7 in. of run-off from their respective drainage areas. This variation results from economic considerations as affected by local conditions and costs. After adjustment for utilisation factor, the minimum regulated flow is expected to be 1,000 cusec.

The Narrows Development

The dam and power house, with ancillary structures and facilities, are located somewhat less than a mile above the mouth of the Tobique River at a point known as The Narrows. This site was selected as most favourable to secure maximum power at minimum cost. The rock formation at this point (and generally throughout the river valley) consists of a shaley limestone finely laminated and badly folded, the laminations standing almost vertical. Exposed surfaces have weathered considerably. In the river bed the softer material has been removed by the turbulent natural flow; and deep potholes occur in the stream bed. A substantial grouting programme was deemed necessary and has been carried out. No solution cavities have been encountered. The dam and power house are located in an area where preliminary geological investigation revealed the rock to be somewhat sounder than in the adjacent areas. The type of rock encountered has been found difficult to excavate to exact line and grade.

A gross head of 78 ft. is available with the headpond at its normal operating level (El. 312) and the normal tailwater level at El. 234. Tailwater elevation fluctuates, however, over a range of up to 18 ft. during periods of flood. The best evidence available indicates that an extreme rise of 29 ft. occurred on June 22, 1922—the date of the maximum flood.

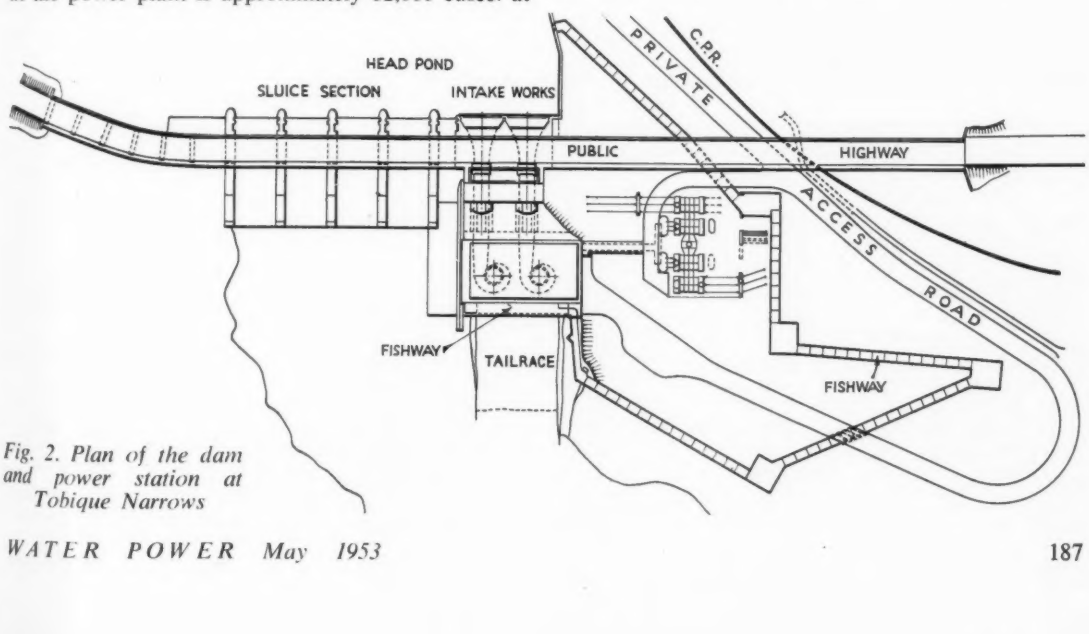
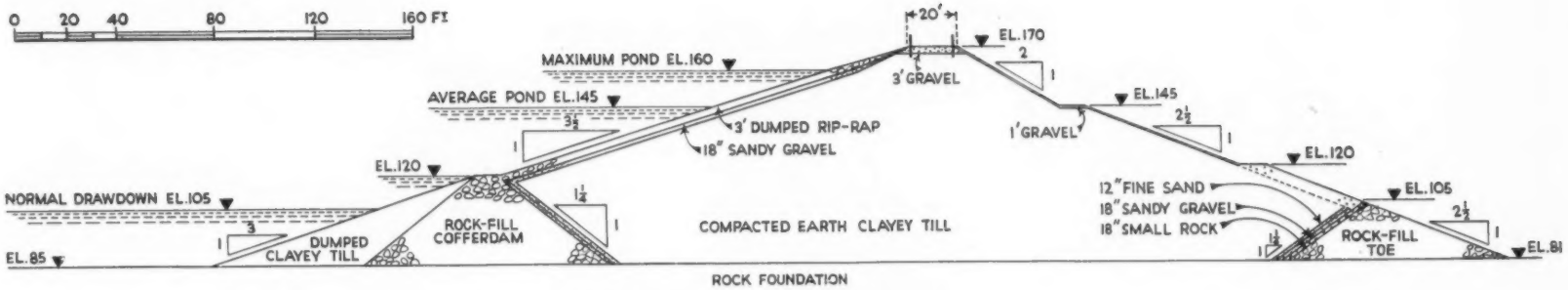
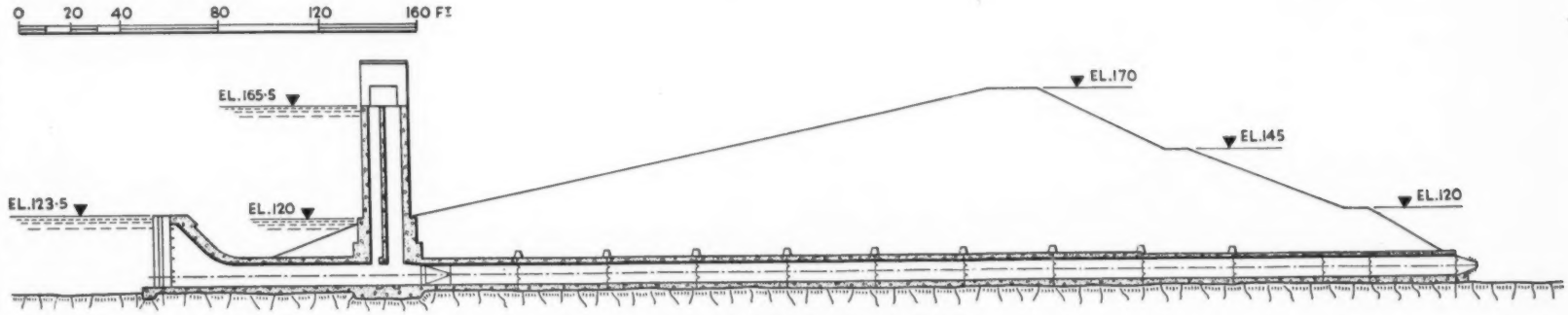


Fig. 2. Plan of the dam and power station at Tobique Narrows



SECTION OF MAXIMUM HEIGHT



SECTION ALONG ℄ OF CONDUIT

Fig. 3. Typical sections through Sisson dam

The Main Dam

The sluice section of the dam spans the main river channel. It is a gravity-type structure surmounted by massive piers for the support of sluice gates, hoists and towers. All sections are designed to resist the combined forces of water pressure, uplift and ice pressure. Uplift is figured at full hydrostatic pressure at the heel, reducing uniformly to zero at the toe, and is assumed to apply on 64 per cent. of the base area. Ice pressure of 10,000 pounds per lineal foot of dam, applied one foot below normal pond level and concentrated at the piers, is assumed.

A model of the dam and power house was set up in the Hydraulic Laboratories of the National Research Council, at Ottawa, to determine the most favourable shapes for the buckets on the spillway, in order to avert scour in the downstream river-bed under various flows and conditions. Tests were also conducted on the model to assure that tailrace velocities would be high enough to attract up-bound salmon into the fish gallery entrances.

Four main sluices and a regulating and trash sluice are provided for flood water discharge. All gates are fixed-wheel type with individual motor-driven screw-stem hoists. Gates and gains are furnished with electric heating elements. Emergency stoplogs and a travelling stoplog hoist are provided.

The sluice dam, north wing and intake works carry a 24 ft. viaduct which is extended southward beyond the intake for an additional 420 ft. It crosses the existing railway as an overpass. The public highway is diverted over this viaduct with suitable approach roads. The old highway bridge located about half a mile upstream from the dam has been removed, as otherwise it would have been submerged by the headpond.

Adjacent to the dam on the north side of the river is a gravity type non-overflow section of dam. On the south side an intake section, complete with trash racks, headgates and emergency stoplogs, is provided. A watertight wall with its top 6 ft. above normal pond level and approximately 1,000 ft. in length is provided to protect a section of the railway line which runs parallel with the river and which could not be relocated in this sector without excessive cost.

Flooding of the river valley upstream from the dam necessitated the purchase and clearing of a considerable land area and the raising and relocation of existing railway tracks bordering the river. The railway is a branch line of the Canadian Pacific Railroad, 25 miles long, serving the town of Plaster Rock, which is also served by the Canadian National. Some three miles had to be relocated and raised where flooding from the forebay would occur. Economic studies were undertaken to determine what advantage would be gained by purchasing and abandoning this branch line, thus enabling an additional 5 ft. to be added to the head. The price asked for the railway, however, proved too high to make this scheme attractive.

The Power House

The power house is of reinforced concrete throughout with watertight walls extending to a height of twenty feet above the generator room floor. This provision was made necessary by the possibility of an extreme rise in tailwater level caused by floods occurring simultaneously on the Tobique and the St. John. Two short steel penstocks, encased in concrete, carry the water from intake to the power house.

In the power house two units are provided, each consisting of an adjustable-blade propeller-type turbine of 13,800 h.p. rated capacity at 75 ft. head. The generators each have a rating of 12,500 kVA or a rated plant output of 20,000 kilowatts of 80 per cent. power factor. Speed of the units is 225 r.p.m.

Selection as to type and size of unit was made by a panel of interested parties after a study of the relative costs and potential energy output, having regard to fluctuating head (due to rising tailwater) and to fluctuating river flow. Another important consideration was the effect of different types of unit upon the descending salmon smolts, many of which would enter the water passages and be carried through the wheels.

Governors and electrical switchgear in the power house are at present arranged for semi-automatic control but may be converted to fully automatic at a future date, if so desired. A high-tension switching structure is located close to the power house, with two 12,500 kVA step-up transformers.

Fishway

In addition to the normal power plant facilities it was essential to provide a fishway to preserve the salmon run in the Tobique River. The Tobique is one of the most important salmon fishing streams in New Brunswick, and substantial revenues are derived from licences to Fishing Clubs.

In co-operation with the Conservation and Development Services of the Federal Department of Fisheries at Ottawa, a fishway some 1,200 ft. long with a lift of 80 ft. was designed. Built of reinforced concrete on rock, with pools 8 ft. wide and 12 ft. long, each with a rise of 1 ft., it is equipped with four downstream entrances above the draught tubes and along the side of the tailrace. Four resting pools are located some 200 ft. apart, each having a surface area of 700 sq. ft. Normal flow is 9 cusec., which can be increased when necessary by an auxiliary water supply through pipes from the forebay to attract the fish to the downstream entrances.

Storage Dams

The headpond resulting from the construction of the dam at the Narrows is some eight miles in length, and has a surface area of about 1,000 acres at normal operating level. Sufficient pondage is thus provided to allow for hourly fluctuation in load without undue loss of head.

The four storage dams included in the current development are all located on the upper reaches of the Tobique watershed, some 50 to 65 miles by road from the power plant. They are accessible over gravelled wood roads built and used by the Frasers' Companies.

For the Sisson Dam, which controls the largest of the four reservoirs, a compacted earth-fill structure was chosen, with a reinforced concrete sluice section at one end to handle the discharge of flood water. There are six openings, sealed by timber stoplogs. One of these openings is reserved for a future log-chute. For regulated flow, water is drawn off through a reinforced concrete pipe placed in a rock trench beneath the dam. The inlet end is equipped with a trash rack and a gate tower is provided near the upper end. This tower is equipped with a main wheeled-type shut-off gate and a similar gate for emergency

Fig. 3. Typical sections through Sisson dam

use. The gate is closed during reservoir filling periods and while cones are being adjusted.

The design of the discharge tunnel and accessories permits the attachment of a penstock to its outlet end to serve a future small power development. A set of removable steel cones serve as an adjustable orifice to control the outflow at various heads. The cone arrangement for discharge control was adopted as an inexpensive, temporary expedient pending construction of this plant.

Trousers Lake dam is a rolled earth-fill structure with a double concrete sluice section placed centrally in the fill. Flood flow, regulated flow and log sluicing are all controlled by removal of timber stoplogs. Serpentine Lake dam, as projected, will be of similar type, with a single concrete sluice section at one end where bedrock occurs at reasonable depth. Long Lake dam is a rock-filled timber crib structure with central stoplog sluice and low earth-fill dykes at each end.

These four storage reservoirs have a combined storage capacity of 187,500 acre ft. when full, but the spring run-off is not sufficient to fill them every year. The cost for additional height of dam and the yield in additional kilowatt hours of energy were the determining factors in establishing the economic height of the controlled pond level. Suitable freeboard for temporary flood surcharge and wave action allowance have been added.

Construction at The Narrows

Concrete for the intake portion of the structure, as well as the trash sluice and one main sluiceway, was placed within the first cofferdam which was built of rockfilled cribs and a portion of one concrete pier on the river side. The rollways of these sluices were left open for passing the flow around the second cofferdam.

Within the second cofferdam, enclosing the remaining three sluiceways, two tunnel openings were left in the No. 3 rollway sufficient to pass an estimated fall flood of some 12,000 cusec. without overtopping the sluiceway sills. Steel closure gates were provided to drop in place for closing the tunnels, after which the openings were filled with concrete.

With the exception of the installation of the sluice gates, headgates, turbines and generators erected by the manufacturers, and of the lighting installation which was a subcontract, all the work on the main dam and power house was carried out by Power Corporation of Canada forces. Some 65,000 cu. yards of concrete were placed and some 30,000 yards of rock were removed.

The force employed varied normally between 250 and 350 men, with peaks of 500 throughout February and March, 1952, and of 400 throughout July and August, 1952. No fatal accident occurred during the life of the job. In spite of numerous delays in the delivery of various items of equipment, due to steel shortages and the consequent necessity for priorities, delivery of power will be only three months behind the scheduled date for completion.

Construction at Sisson

The fill material used for the Sisson earth-fill dam was a heterogeneous glacial till, obtained from borrow pits within a third of a mile from the site. Excavation and placing was carried out with a swing of three 20-yard and one 12-yard carryalls, together with from one to three 10-yard rubber-wheeled scrapers. From nine to sixteen trucks were also used for hauling, and were assisted for loading, spreading and rolling by three shovels and six tractors and bulldozers. Some double-shifting was done during part of the construction period to make up time lost through wet weather.

Compaction was effected with heavy sheepsfoot rollers having foot pressures of 500 lb. per square inch. Pneumatic tyre rollers were also tried, but were found unsuitable due to the high percentage of clay content in the fill material, and the limited working area available.

Some 400,000 cu. yards of foundation excavation, stripping, earth fill, gravel facing and rock fill, were handled over a period of eighteen weeks for the Sisson main dam and for three small dykes over nearby ravines. Rock for riprap facing and for upstream and downstream rockfill toes was quarried from the sluice channel below the sluiceway structure and dumped in place.

To save the hauling of a large volume of gravel and sand from remote sources, no drainage blanket was placed under the downstream toe to lower the seepage line. To compensate for this the downstream rock toe was increased in size. The scarcity and high cost of gravel precluded its use on the downstream slope. Protection from erosion will be achieved by seeding this face next season with clover and grass.

Engineering and Construction

Power Corporation of Canada Limited, as consultants and agents for the New Brunswick Electric Power Commission, are responsible for design and construction of the development at The Narrows; and for design and supervision of construction of storage dams. Work involved in the relocation of existing railroad and public roads was carried out by local contractors to plans and specifications prepared by the Commission.

Galloway Water Power Development

Mr. F. H. Williams, B.Sc. Tech., (Manchester), M.I.C.E., M.I.E.E., retired on 31st March from the position of Hydro-Electric Engineer, South-West Scotland Division of the British Electrical Authority. When the first stage of the Galloway Water Power Company's scheme was nearing completion in 1934, he was appointed manager of the company, and thereafter was responsible for the starting up and operation of the stations and the maintenance of the civil engineering works and generating plant. He held that appointment and was also a director of the company when it became vested in the B.E.A. on 1st April, 1948. The Galloway water-power scheme, it will be recalled, was the first of its kind in this country. It has created wide interest and has been inspected by thousands of engineers and others from all parts of the world. Its novel features were (i) the use of a single river and its tributaries to generate electricity by water power to assist the peak load on the grid, and (ii) the remote control, by means of supervisory equipment, of two automatic water power stations connected direct to a 132,000 V grid. Briefly, the flow of the Galloway Dee, in passing through five power stations within a distance of 25 miles, operates 105,000 kW of generating plant of which the average output per annum has been over 230 million units ever since completion of the development in 1938.

Water Turbine Governors and the Stability of Hydro-Electric Plant

In this series of articles, the water-turbine governor is considered in relation to control of the electrical transmission network, as well as to regulation of the water supply system, including the surge tank. The principles underlying the design and operation of water-turbine governors are reviewed and a typical oil-pressure governor is described in some detail, along with its pressure oil supply. A short general account of the double regulation system for water turbines is then given, and is rounded off by a discussion of the stability of water-turbine governors.

By N. G. DENNIS, M.A., D.I.C., A.M.I.Mech.E., A.M.I.E.E.

PART FOUR

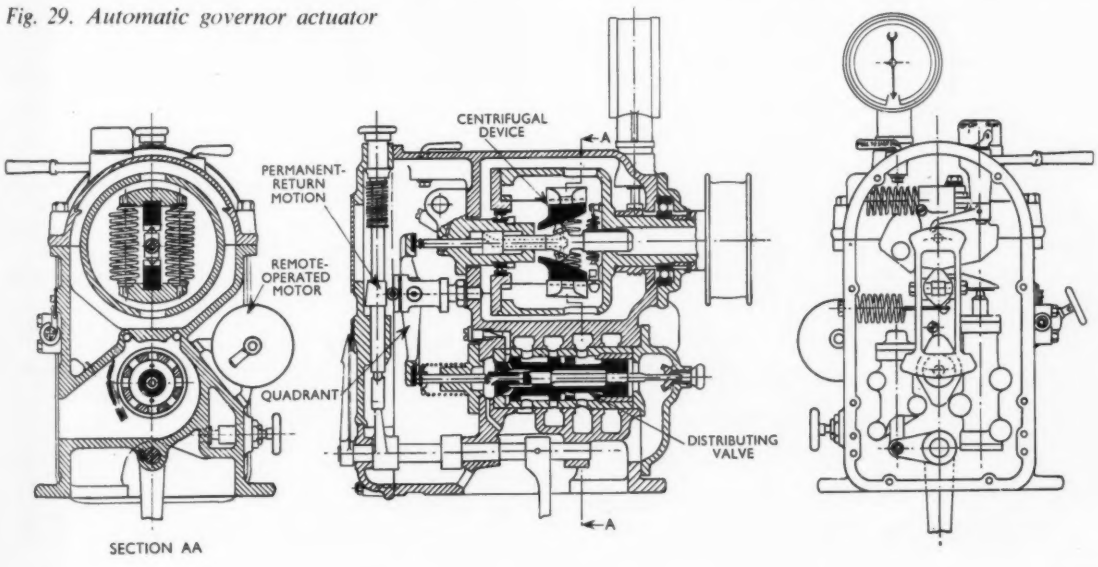
THE following description of an individual governor is included to illustrate the general analysis of water-turbine governors which has been given in the previous articles. Readers are invited to apply this type of concise analysis to any other governor with which they are familiar.

Water-turbine governors have been made for many years by the English Electric Co. Ltd. Fig. 29 shows one model of the actuator. The actuator contains most of the low-power side of the control system (Fig. 4) and usually is mounted on a servomotor. According to the turbine size and layout, this servomotor can be either a pilot servomotor which controls the oil supply of the main servomotors through a distributing valve, or it can be actually the main servomotor. Fig. 30 shows the actuator mounted above such a main servomotor in a non-enclosed arrangement. A diagram of this arrangement is given in Fig. 31, while Fig. 32 is a photograph of the centrifugal device and the combination element (see Fig. 4). Fig. 33 is a block diagram of this actuator and servomotor.

The centrifugal device is of the type shown in Fig. 14. The governor has a temporary-return motion (Fig. 21a), the location of which is shown in the bottom right-hand corner of Fig. 29. The permanent-return motion is produced by the vertical movement of the spindle mounted behind the front cover of the actuator, and this incorporates a cam with an inclined face which bears against a roller arranged to move horizontally.

The combination element in this case combines the speed deviation, the temporary-return motion, the

Fig. 29. Automatic governor actuator



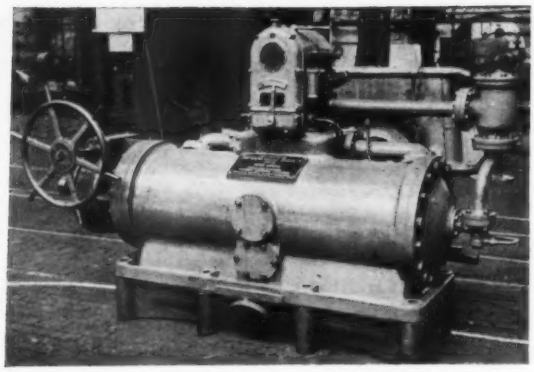


Fig. 30. Governor actuator and servomotor

permanent-return motion, and the change-of-speed movement. It consists mainly of a special quadrant, shown in Figs. 29 and 31, which covers all the elements mentioned above, with the exception of the change-of-speed which is added later in the sequence. The quadrant is a floating lever (Fig. 15) having an extra degree of freedom provided by a transverse swivelling action. The ends of the quadrant have inclined faces whereby the transverse rotation produces relative movement between spindles bearing against the faces. The summated movement from the quadrant operates the distributing valve through a pilot nozzle of the type shown in Fig. 17a. The change-of-speed movement is introduced by varying the position of the nozzle relative to the piston of the distributing valve. This is done by mounting the nozzle at the end of a spindle which is screwed into the piston of the distributing valve. A motor remotely operated controls the setting of the change-of-speed device. Rotation of this motor causes the screwed spindle within the distributing valve body to rotate to a new position, thus adding the change-of-speed movement to those elements already combined in the quadrant. In effect, the change-of-speed action is produced by varying the length of the spindle between the quadrant and the distributing valve.

The temporary-return motion is of the type shown in Fig. 21a, the distribution valve and servomotor being arranged to integrate as in Fig. 7a. Fig. 34 is

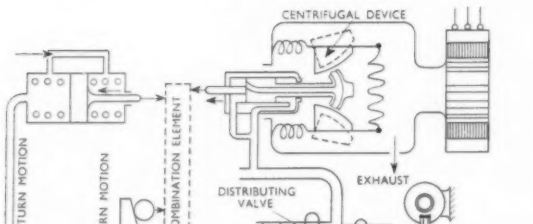


Fig. 31. Diagram of water-turbine governor

an example of a typical load-rejection response curve for this model of governor.

As has been mentioned before, such governors must be designed for the personnel, as well as the technical conditions prevailing at site. The generating set is often situated in remote parts of the world, and therefore one must design the governor to be as simple and reliable as possible. This, of course, means sturdy construction and proper enclosure and protection of all delicate mechanism. Accessibility and maintenance must be made as easy as possible. At the same time, the sensitivity and rapidity of action of the governor must satisfy amply the requirements of the electrical network.

To ensure minimum wear and maximum life all working parts of the governor are lubricated automatically. Oil strainers guard against the entry of foreign matter. The servomotors can be hand operated in case of emergency. Different arrangements of servomotors are used for different conditions.

It is essential that all such governors should be tested thoroughly at the factory before despatch. The final settings of the various devices on a governor can be done only under site conditions, and easy adjustment is provided.

The actuator is standardised for various sizes of turbine and for the various types of control and pro-

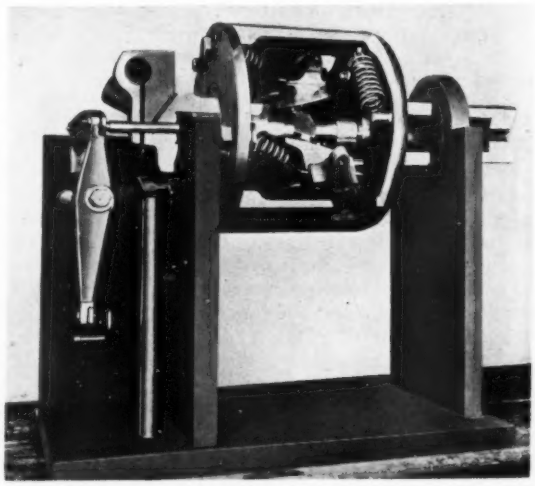


Fig. 32. Cut-away centrifugal device and combination element

tective systems. Control schemes have been extended to cover complete automatic control with remote supervision and operation, including the starting and stopping of the turbine from a distant point. Such control schemes necessitate the closest co-operation between all the engineers concerned.

Simple Governor Theory

Although this theory embraces the main influences on water-turbine regulation, there are many other factors which may affect the results obtained. The theory given below applies specifically to the temporary-return-motion governor, but the theory for acceleration-sensitive governors is very similar and leads to the same general condition of stability.

The assumptions made in this simple theory are:—

(1) The generator supplies a purely resistive load under the influence of an infinitely rapid voltage regulator, so that the electrical power which resists the rotation of the main shaft remains constant during transients. In practice, this assumption is unfavourable to the governor since it means that the resisting torque will decrease as the speed increases. Hence, the speed increase will be exaggerated and stability worsened.
(2) Constant efficiency of the turbine over its range of transient operation.
(3) Travelling pressure waves, due to water hammer in the hydraulic system, are ignored and the water is considered as a concentrated mass.
(4) Negligible time delays in the centrifugal device and in the relays of the governor.

NOTATION

K_0 A constant, defining the rate of action of the distributing-valve and servomotor.
T_r Time constant of dashpot.
y_0 Steady-state opening of the guide vanes.
ϵ Relative increment of guide-vane opening.
ζ Relative increase in head due to water-hammer.
η Effect of temporary-return motion as described by a relative speed increment (hypothetical) which would affect the distributing valve by the same amount.
θ Time constant of the hydraulic conduit (ratio of the momentum of the water to the product of the head and the acceleration due to gravity).
ξ Relative speed increment (ratio of actual increment of speed to steady-state speed).
σ Stroke of temporary feed-back (measured as though the dashpot were rigid).
τ Time constant of rotation of runner-rotor (ratio of kinetic energy at normal speed to steady-state power).
τ' A characteristic time, describing the slowness of regulation of the whole governor.

Equation of Centrifugal Device, Distributing-valve, Servomotor and Return Motion

$$\frac{d\epsilon}{dt} = -K_0(\xi+\eta), \quad . \quad . \quad . \quad . \quad (1)$$

where $\xi+\eta$ describes the displacement of the distributing-valve due to the sum of the displacements of the centrifugal device and the return motion. The rate of movement of the servomotor is proportional to this. The effect of an acceleration-sensitive device can be added if desired.

Equation of Dashpot in the Temporary-return Motion

$$\frac{d\eta}{dt} = \sigma\frac{d\epsilon}{dt} - \frac{1}{T_r}\eta \quad . \quad . \quad . \quad . \quad (2)$$

With reference to Fig. 23(b), this equation equates the velocity of the output to the velocity of the input minus the relative velocity of the piston within the dashpot.

Equation of Rotation of Runner and Rotor

$$\tau\frac{d\xi}{dt} = \epsilon + \frac{3}{2}y_0\zeta \quad . \quad . \quad . \quad . \quad (3)$$

Acceleration is the effect of increased driving torque due to the change in the guide-vane opening and the increase in water pressure due to bulk water-hammer. The stabilising effect of self-regulation can be introduced into this equation if desired.

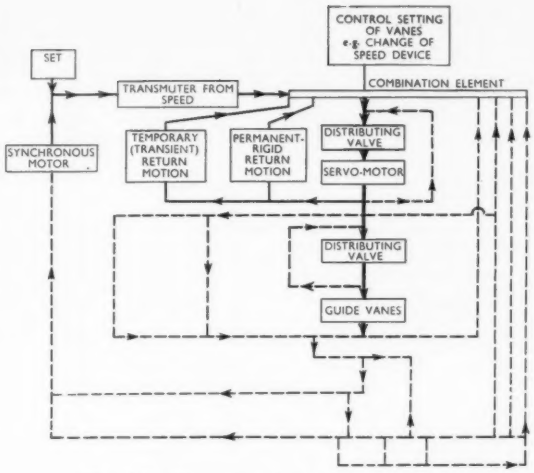


Fig. 33. Diagram of governor action

Equation of Bulk Water-hammer

$$\zeta = -\theta\left(\frac{d\epsilon}{dt} + \frac{1}{2}y_0\frac{d\zeta}{dt}\right) \quad . \quad . \quad . \quad . \quad (4)$$

The pressure rise is proportional to the deceleration of the water in the pipe-line. This deceleration is the combined effect of the rate of closure of the guide vanes and the rate of increase of pressure. This effect is to produce instability.

Overall Response Equation. The overall response equation, as derived from the above four equations, is

$$\frac{\tau\theta y_0}{2}\cdot\ddot{\xi}+\tau\left(1+\frac{y_0\theta K_0\sigma}{2}+\frac{y_0\theta}{2T_r}\right)\dot{\xi}+$$
$$\left\{K_0(\tau\sigma-y_0\theta)+\frac{\tau}{T_r}\right\}\dot{\xi}+K_0\left(1-\frac{y_0\theta}{T_r}\right)\xi+\frac{K_0}{T_r}=0 \quad (5)$$

The distributing valve and servomotor can usually be assumed to act very quickly and hence K_0 can be assumed infinite.

This reduces the equation to

$$\frac{\tau\theta\sigma}{2}\dddot{\xi}+(\tau\sigma-\theta)\ddot{\xi}+\left(1-\frac{\theta}{T_r}\right)\dot{\xi}+\frac{1}{T_r}=0, \quad (6)$$

when the turbine is operating at the most unstable condition, which is usually at full load ($y_0=1$). When the Routh stability criteria are applied to the coefficients of equation (6), the following two conditions result:—

Condition (1)

$$\sigma > \frac{\theta}{\tau}$$

This is identical with the condition mentioned by Thoma (1924) for permanent-return-motion governors. It specifies the minimum stroke of the temporary-return motion.

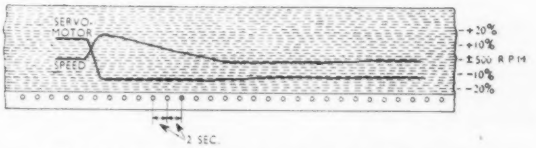


Fig. 34. Typical response curve of governor
Rannoch No. 3 Machine, 15,060 kW thrown off

Condition (2) (Almeras 1946, and Gaden 1945)

$$\frac{(\sigma T_r)\tau}{\theta^2} > 3{\cdot}74$$

Now the slowness of regulation of the whole governor is controlled by the tempory-return motion, that is σ and T_r and, in fact,

$$\tau' = \sigma T_r$$

Therefore,

$$\tau'\tau > 3{\cdot}74\,\theta^2.$$

Thus the product of the slowness of regulation (a time τ') and the time constant τ of the runner-rotor, cannot have a value less than the value determined by the hydraulic conditions.

Further Considerations

There are many factors which also affect the stability of governing of the individual generating set. Stability is improved if:—

(1) The efficiency increases as the gate opening increases. This provides for alteration in the turbine power with a smaller change of flow through the turbine. Hence, one unstabilising influence—that of water hammer—is reduced.

(2) The customer's load embodies appreciable inertia. Such inertia is, of course, coupled electrically to the flywheel effect of the generating set. Although this electrical coupling is not absolutely rigid, it has a very beneficial effect on stability. Evidently, any increase in the moment of inertia will improve regulation, since the stored energy in the system is then increased and is available to aid the governor action during load changes.

(3) There is favourable difference between the power-frequency characteristics of the generating set and of the load. This property is called 'self-regulation,' which can be described most conveniently by considering the steady driving torque of the turbine relative to the steady resistance torque provided by the electrical load. The turbine driving torque will always decrease with an increase in speed, whereas the resisting torque will usually increase. The difference tends to slow down the generating set, and constitutes a corrective and stabilising influence.

In general, the magnitude of the electrical load is dependent on the voltage as well as on the frequency supplied by the generating set. Since any voltage regulator gives a transient voltage rise when the speed increases, a further increase in the resistance torque results, with consequent improvement of stability. The effect occurs to some extent with any voltage regulator but is more pronounced with older designs. The latest automatic voltage regulators tend to be very rapid in action and should be considered carefully in this connection, since they reduce the 'artificial' self-regulation due to transient-voltage change.

Statistical analysis has been employed to ascertain the total self-regulation effect of the miscellany of loads connected to a power system.

Sometimes governor tests are made during the commissioning by means of water-resistance load on the generating set. Such conditions will usually constitute an abnormally severe self-regulation effect, and the turbine governor should not be adjusted finally during such tests.

A further influence on stability is the travelling wave of water hammer in the pipelines of high-head plants (see Gaden and Neeser 1948 and Gaden 1945). Such water-hammer waves, of course, occur in the supply and discharge conduits of every plant. However, with low and medium-head plants, the wave action is negligible and the effect is as though the water were concentrated in a single mass. With high-head plants it is important that the governor does not resonate with the water hammer.

These influences can be taken into consideration by modifying the formula $\tau'\tau > 3{\cdot}74\,\theta^2$ into $\tau'\tau > K\theta^2$ where K is a function of the influences described.

It should be mentioned that double regulation cannot be regarded as affecting the stability of small oscillations. It affects only the amplitude of large oscillations, since the deflector, diffuser and relief valve bring about a transient flow diversion only for big load rejections and not for increases, nor for very small decreases, of load. This transient flow diversion could be arranged to improve stability, but only at the price of a continual waste of water. The runner blades of a Kaplan turbine usually move slowly in relation to the guide vanes and thus do not influence stability to any great extent.

On some large power systems, many generating sets are operated at a fixed gate opening, i.e. the opening is not decided by the frequency but by the river flow with a run-of-river plant, or by the water level in the case of a power station having large reservoir capacity. Such plants can be considered to have an infinite slowness of regulation and, from Condition 2 of the Simple Governor Theory, it will be seen that this means ample stability. However, frequency regulation would be bad but for the facts that special frequency-control plants are provided, and furthermore that the electrical networks are extremely large. It can be shown statistically that the frequency deviations due to load changes on the network are roughly proportional to the square root of the total power capacity of the network. Obviously, a sudden 10 MW load change will produce a greater frequency deviation on a small network than on a large one.

The quality of frequency regulation also is roughly proportional to the rapidity of action of the governors controlling the frequency; and the error in frequency varies as the slowness of the governor regulation. It may be noted here that with any servo system there is a certain conflict between the attainment of stability and the attainment of accuracy of control. Accurate control demands a high rate of action of the controlling mechanism and this is limited by the incidence of instability.

A few further words are necessary concerning the electrical stability of power systems. Space does not allow a detailed consideration of this subject to be given in these articles but at the very least it should be realised that this is an extremely important and complex subject. In general it concerns the pole swinging of the synchronous generators and motors connected to the power system particularly after severe electrical faults, which of course constitute a sudden shock loading of the system. It is usual practice to ignore the influence of the rapidity of action of the governor on the transient stability. The reason for this is that governors are relatively slow in action compared with the time constants which control these power-system oscillations. Nevertheless an improvement in the rapidity of action in the governor does have a slight improvement on the transient stability because within the practical limits

possible, the turbine output is more rapidly reduced subsequent to a severe drop in generator load due to a fault. If possible the time lag of the governor and its natural frequency of oscillation should not approach the natural period of the electrical system since this can bring about resonant oscillations. On the other hand, governors have an important effect on the steady-state stability since they control the division of the load changes amongst the various generating units and hence the behaviour when the limit of static stability is approached.

Likewise the rate of action of the generator excitation system as influenced by the voltage regulator has no great effect on transient stability, but is important in connection with steady-state stability. A fast rate of action enables operation to be nearer the steady-state-stability limit since a smaller margin can be allocated to deal with normal perturbations occurring in the system. There is thus a certain amount of conflict concerning the desirable rate of action of the voltage regulator since an increase in its rate of action, although improving system stability, has a detrimental effect on the self-regulation discussed previously.

As regards the earlier basis for the determining of the requisite moment of inertia, Almeras has shown that these prescribed conditions have a certain logical basis. He has shown that the stability and the quality of regulation correspond roughly to the product of the rise in pressure and the rise in speed on sudden rejections of load. Thus in the modern view, importance is not placed so much on the overpressure or the overspeed as such but rather on their product. While the values of overpressure and overspeed concerned are those obtaining without relief valve, deflector or diffuser, this is not always the case in the practical application of the earlier basis, which contributes further to a lack of theoretical integrity.

This series should not be concluded without due acknowledgment to The English Electric Co. Ltd. for permission to use and publish information. I am greatly indebted to my colleagues for assistance in various ways and am specially grateful to Mr. E. N. Webb for his sustained interest and his help with the text.

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Abstracts from the World Technical Press

Adige-Lake Garda Development

A multi-purpose development is discussed, which aims at exploiting the level differences between the lake and the river flowing parallel to it for power generation, irrigation, and flood control. The scheme advocated is a synthesis of a number of studies made previously, and proposes to connect the river south of Mori with the north-eastern tip of the lake. A tunnel will be constructed south of Torbole to the small Loppio lake, about halfway to the river, and will serve as a balancing reservoir. Part of the water impounded would return to the river through a shorter tunnel between Lazise, on the south-east bank of the lake, and Pastrengo, near the point where the Adige turns east towards Verona. This latter tunnel could, in addition, divert flood waters from the river to the lake.

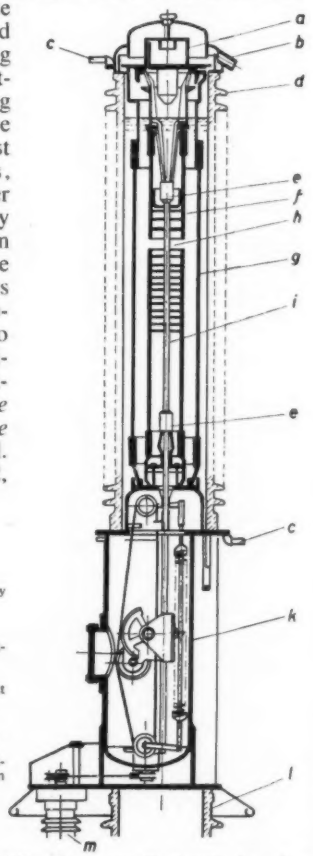
The possibility of regulating the lake is examined in detail with a view to utilising its waters, as well as those diverted from the Adige, mainly for irrigation in the summer, and hydro-electric generation in the winter.

This interesting development would thus co-ordinate flood control with a wider utilisation of the hydraulic resources of the system for the substantial benefit of both industry and agriculture. (Ernesto Armellin, *Giornale del Genio Civile,* Vol. 90, No. 11, Nov. 1952, p. 644, 10 pp., 6 ff.)

A New Circuit-Breaker

A description is given of a new "orthojecteur" circuit-breaker for a 220 kV system, together with a detailed account of the tests carried out with this apparatus at the switching station at Fontenay, near Paris, one of the most important junctions of the French 220 kV grid. This low oil content circuit-breaker (diagram appended) is an improved design of the well-known Sprecher-&-Schuh circuit-breaker with a three-phase group consisting of three identical unipolar breakers which can be indifferently either coupled mechanically or operated by three electrically coupled individual controls.

Three series of tests were effected: short-circuit breaking tests between phase and earth, short-circuit breaking tests between phases, and circuit-breaking tests on lines on no load up to a total length of about 510 miles. All these tests, which included the repeated breaking of the maximum short-circuit load occurring at Fontenay, gave without exception most satisfactory results, and the circuit-breaker was still in practically mint condition when the tests ended. The contacts themselves could have been submitted at once to several series of similar tests. (H. Ehrensperger, *Bulletin de l'Association Suisse des Electriciens,* Vol. 43, No. 18, 6.9.1952, p. 730, 8 pp., 10 ff.)



a. Oil separator and safety valve.
b. Cover with gas outlet.
c. Current supply.
d. Insulator of contact chamber.
e. Upper and lower contacts.
f. Upper and lower contact pots.
g. Contact chamber.
h. Gap between contact pots.
i. Contact Tube.
k. Chamber containing operating gear, and inspection window.
l. Insulating support.
m. Rotating spindle.

Fig. 1. Arrangement of "orthojecteur" circuit-breaker

Reversible Pump Turbine

The function of this pump turbine, which has been developed by Allis-Chalmers Manufacturing Company, is to provide stored hydro power by pumping water from a suction pond at a low elevation to a storage lake at a higher elevation. The equipment

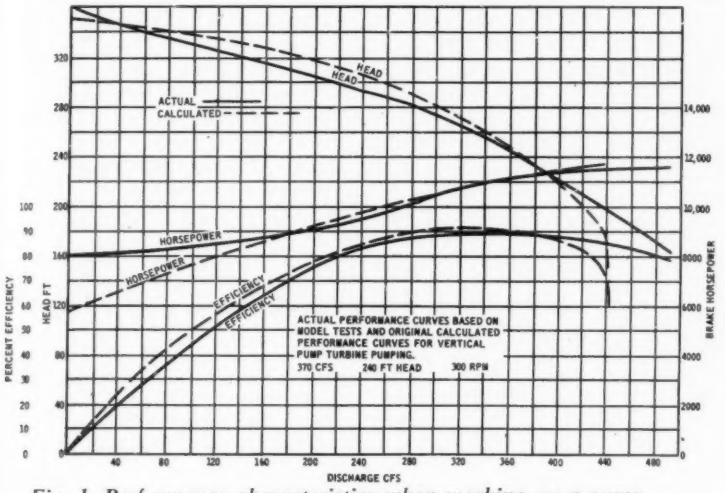


Fig. 1. Performance characteristics when working as a pump

can then utilise this stored energy by developing power as a hydraulic turbine when the flow is reversed, passing from the storage lake to the suction pool. It is a vertical unit and resembles a Francis turbine, having a conventional spiral case and draught tube. It is direct connected to an electrical machine which serves either as a motor or a generator.

Normally, it will operate at 300 r.p.m. for pumping and at 257 r.p.m. for generating power. While it can operate as a generator at either 300 r.p.m. or 257 r.p.m., depending upon which system of poles is cut into the circuit, it will develop a considerably greater output and attain a better overall efficiency at 257 r.p.m. On the other hand, best overall pumping efficiency is obtained at 300 r.p.m.

When started up as a pump at 300 r.p.m., the butterfly control valve will be closed and the motor will supply the shut-off horsepower of about 8,000 h.p. As soon as pressure builds up in the casing, the valve will be opened and the water carried up the penstock to the storage lake. When the valve is fully opened pumping will proceed from the minimum head of 170 ft. to a maximum head of 300 ft. At the end of the pumping cycle the pump will be shut down until the next generating period.

For laboratory test purposes, a scale model was built having a ratio of 1/5·26 to the larger unit. Fig. 1 shows the performance curves for pumping. The head and horsepower are stepped up from the model test, while the efficiency shown is that obtained on the model. It is expected that the efficiency will be from one to two per cent. better on the large unit. It will be noted that the maximum horsepower required from the motor will be about 11,500. The maximum shut-off head with the butterfly valve closed will be 360 ft.

Fig. 2 shows the performance curves for the turbine operating at 300 r.p.m. and 257 r.p.m. It will be noted that the horsepower is 12,600 at 290 ft. head for either speed. However, as the head goes down, the horsepower output is considerably higher at 257 r.p.m. than at 300 r.p.m. For example, at the minimum head of 140 ft., the output would be zero at 300 r.p.m., while at 257 r.p.m. it would still be about 3,400 h.p. Again, as in Fig. 1, the horsepower was stepped up from the model test, but the efficiency shown is the efficiency obtained in the model test. The efficiency curve at 300 r.p.m. drops quite steeply with reduction in head, while at 257 r.p.m. it is admirably flat. At 140 ft., where the efficiency is zero at 300 r.p.m., it is still 75 per cent. at 257 r.p.m. It is expected that the efficiency of the larger unit will be one to two per cent. higher than these figures. (Frank E. Jaski, *Allis-Chalmers Electrical Review*, 4th Quarter, 1952, p. 8, 4 pp., 5 ff.)

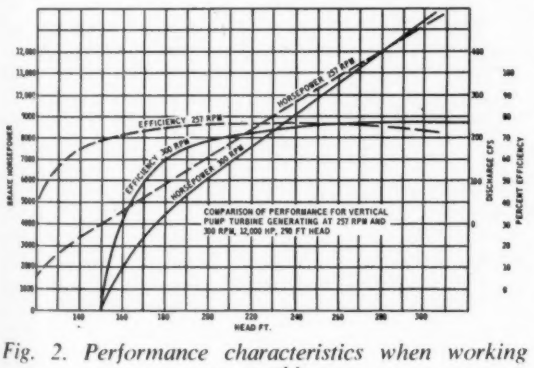

EFFICIENCY 257 RPM
HORSEPOWER 257 RPM
EFFICIENCY 300 RPM
HORSEPOWER 300 RPM
COMPARISON OF PERFORMANCE FOR VERTICAL PUMP TURBINE GENERATING AT 257 RPM AND 300 RPM, 12,000 HP, 290 FT HEAD
BRAKE HORSEPOWER
DISCHARGE CFS
PERCENT EFFICIENCY
HEAD FT.

Fig. 2. Performance characteristics when working as a turbine

Harnessing an Underground Stream

The Gave d'Ossau, Gave being the name given to many mountain streams in the Pyrénées, consists of a series of three power plants, Artouste, Miègebat and Le Hourat, of which the first one plays no part in the installation under review. A supply canal connects its intake on the Sousoueou, a right-bank tributary of the Gave upstream of Miègebat, with a surge tank from which penstocks convey the water to the Miègebat plant; the water utilised there then flows northward to the Hourat plant in a canal parallel to the Gave. Recently, the discharge of another right-bank tributary has been diverted to Miègebat, which sounds quite fantastic since it joins the Gave downstream of that plant, to say nothing of the fact that the sill of the grotto through which it reaches the open air is 164 m. below the level of the Miègebat intake canal.

After a thorough exploration of the underground course of the stream, the Fayolle waterfall, discovered in 1928 817 m. from the mouth of the grotto, appeared to be a very suitable spot for an intake, as the crest of the waterfall was at about the same elevation as the maximum level in the Miègebat surge tank.

Following exhaustive underground and surface surveys, a tunnel 541 m. in length, with a gradient of no more than 1 in 6,666, was driven from the Miègebat surge tank in the direction of the Fayolle waterfall and ran into the cave exactly at the site of the waterfall; it was even found possible to utilise a natural hollow below the waterfall in the rock, so that no intake structures had to be set up.

No less than about 12 million cu. m. of water are now diverted every year into the Miègebat surge chamber, producing at both downstream plants, under an aggregate head of 584 m., 14 million kWh at a cost of 2 fr. per kW/year, as against 40 and even 50 fr. in large-scale developments of the classic type. The total expenditure involved in the driving of this tunnel and in its equipment, amounting to 28,000,000 Fr. or about £28,000, will have been fully redeemed in less than six months, and operating costs are practically nil. (M. Chamayou, *La Houille Blanche*, Vol. 7, No. 6, December 1952, p. 802, 7 pp., 7 ff.)

Rock Excavation Equipment

This second instalment of the study briefly reviewed in our last February issue (p. 79) deals with the various types of cut, the use of explosives, as well as results and costs. Costs which, of course, apply to conditions prevailing in India, are analysed in separate tables for mucking, drilling in open-cut work as well as in tunnels, drilling in general, and rock blasting. (S. C. Kale, *Indian Journal of Power and River Valley Development*, Vol. 2, No. 10, September 1952, p. 18, 7 pp., 5 tables, 3 ff.)

Töss Valley Development, Switzerland

The Töss river is a right-bank tributary of the Rhine on its Lake Constance—Basle stretch which it joins due north of Zürich after flowing through one of the main centres of the Swiss textile industry. Actually the hydro-electric development of the river followed hard on the heels of industrial development. The first spinning mills appeared there at the beginning of the nineteenth century, and began to discard the old water wheels in favour of turbines about 30 years later. Today the valley offers a typical example of small-scale developments well adapted to requirements.

The 23 plants scattered on a stretch of about 20 miles have an aggregate capacity of 5,401 h.p., *i.e.* on the average no more than 260 h.p. per plant. The net head, totalling 117·87 m., varies between 1·80 and 8·60 m. for each plant, the gross head, between Wila and the Rhine, being 220 m. The smallest discharge per second is but 0·6 cu. m., whilst the greatest does not exceed 7·8 cu. m. Thirteen plants are equipped with Francis, nine with Kaplan, and one with Girard turbines. The 12 plants in the upper valley are built on a 11 km. long canal, with three reservoirs for daily compensation; of the seven plants on the middle course of the river, near Winterthur, five are set up on a canal, and there is no balancing reservoir; in the lower valley, the two upper plants draw their water supply from a canal, while the two lower ones have a compensating reservoir. In spite of the difficulties, due, above all, to the filling of the reservoirs, and in spite of operating and maintenance costs which are relatively much higher than in large plants, the Töss Valley installations give, on the whole, satisfactory results. Many of the plants are coupled with the Zürich Canton system, which absorbs their surplus energy. (Dipl. Ing. W. Pfeiffer, *Wasser- und Energiewirtschaft*, Vol. 43, No. 8, August 1951, p. 142, 6 pp., 10 ff.)

The Peyrat-le-Château Plant, France

While the steep and narrow valley of the upper Vienne does not lend itself to the setting up of large structures and the storage of great masses of water, the Maulde, one of its right-bank tributaries, flows into a wider valley about 10 km. to the north of the Vienne, and by raising its level about 30 m. near Vassivières a storage reserve of 100 million cu. m. is created, ensuring an average production of 110 million kWh per annum. In its main lines this important development scheme comprises:—

(a) A large reservoir in the Maulde valley for which an adequate supply of water is ensured by diversions connecting, successively, the upper stretch of the Vienne in the Corrèze Département with three right-bank tributaries — the Chandouille, the Dorat and, finally, the Maulde itself;

(b) An underground power station near Peyrat-le-Château, operating under a head of over 250 metres;

(c) A small auxiliary generating plant at Faux-la-Montagne* utilising the drop between the Dorat reservoir and the upper Maulde.

The highest supply point of the scheme (745 m. O.D.) is a small reservoir created by a low dam (4 m.) at Servières on the upper stretch of the Vienne from which the water flows through a natural channel, appropriately fitted up, to the neighbouring valley of the Chandouille, where it is stored behind the 17 m. high Chammet dam at 715 m. O.D. This is a rock-fill structure built throughout on a concrete apron, fitted with numerous cross-drains, and traversed by a free-flow tunnel equipped at either end with butterfly valves. The Chammet reservoir connects in its turn, by means of a tunnel 3 km. long and 5·6 sq. m. in cross section, with the Dorat, whose slightly widened bed forms the continuation of this tunnel and conveys the water to the Faux-la-Montagne reservoir at 705 m. O.D. This reservoir is created by a multiple-arch buttress dam 15 m. in height and its north-west bank is only 180 m. away from the south bank of the Maulde, both banks being connected by an open channel at the northern end of which a small 3,000 kVA generating plant utilises the 30 m. head available at this spot. The Maulde provides this plant with a natural tailrace and leads to the main storage basin of the scheme near Vassivières. This main reservoir is closed at the north-west end by the Vassivières dam and an auxiliary dam.

The Vassivières dam is of the orthodox gravity type with a batter of 1 : 20 on the upstream face and 3 : 4 on the downstream face, the release of flood water being effected by two spillway passes fitted with automatic gates. Downstream of the Vassivières Dam, the Maulde forms a wide loop with a very steep gradient which gives a head of no less than 253 m. Confronted by the alternative of harnessing this head either in a single step or in two steps of 200 and 50 m. respectively, the engineers responsible adopted the former solution for reasons of economy. The main

* The Faux-la-Montagne Dam is described in WATER POWER, April 1952, p. 153.

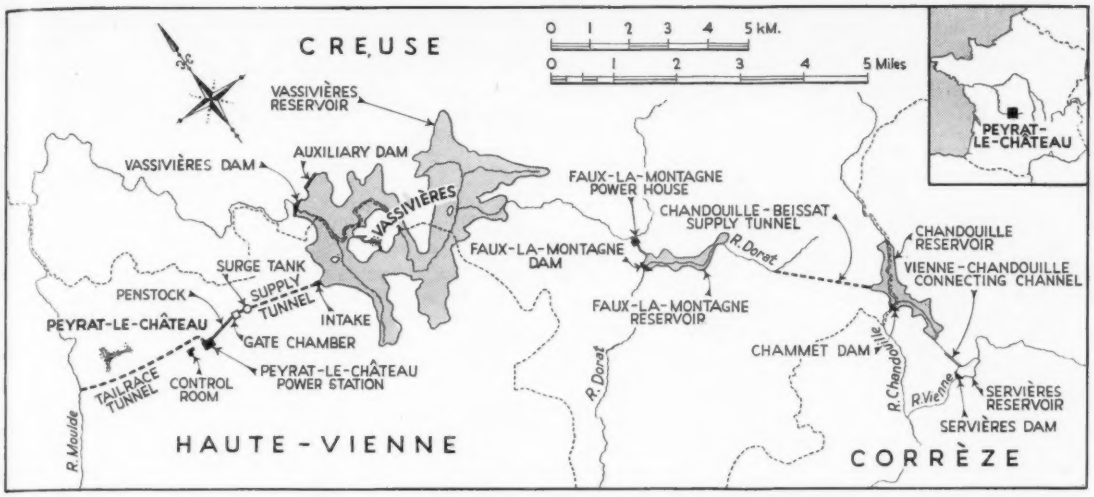


Fig. 1. General map of Upper Vienne development

power station, situated about half-way between the south-west bank of the Vassivières reservoir and the Maulde, due east of Peyrat-le-Château, is built in a cavern 42 m. in length by 11 m. in width and 17·5 m. in height; the flow of 27 cu. m. per second drives three Francis turbine sets generating 21,000 kVA. There is but one penstock, 610 m. in length, with a diameter varying between 2·80 and 2·30 m., and without expansion joints, the final 140 m. being laid in an inclined shaft with a gradient of 4·5 : 10. The tailrace is constituted by a free-flow tunnel 3,800 m. in length and 11·5 sq. m. in cross-section. The control room, which stands above ground, connects with the power station by means of a 400 m. long tunnel with a gradient of 1·1 : 10. (*La Houille Blanche*, Vol. 7, No. 5, Oct.-Nov. 1952, Pictorial Supplement, p. 739, 12 pp., 28 ff.)

Testing Concrete Aggregates

In this report, submitted to a Subcommittee of the American Society for Testing Materials, an improved uniformity of the Accelaret Soundness Test of Coarse Aggregate is suggested. The development of the present standard gradings used in this test is described with an explanation of a reason for the lack of agreement among different laboratories in check tests of the same aggregate. To correct this difficulty, the use in the accelerated soundness test of a single grading for the test sample which is applicable to the grading of all coarse aggregates occurring in concrete, and the use of "half-size" sieves to determine the portion of the sample which has suffered disintegration or multiple cracking, are recommended for immediate adoption. With the application of this method, losses of 6 to 9 per cent. may be substituted for losses of 10 to 15 per cent. as determined by the present method of test in which combinations of individual sizes of coarse aggregates are involved. Until such time as the method of tests can be rewritten and published, the immediate revision of specification requirements for coarse aggregate is advocated to ensure that material of a known quality will be obtained. With the revised method, the concordance of test results obtained by different laboratories should be improved to a marked extent. (D. O. Woolf, Senior Materials Engineer to the Physical Research Branch of the Bureau of Public Roads, Department of Commerce, Washington, D.C., *ASTM Bulletin*, No. 187, Jan. 1953, p. 42, 4 pp., 1 f., 1 table.)

Albula-Julia Development

The city of Zürich draws a substantial part of its electric energy from as far as the Grisons canton, and actually owns the whole of the Alba-Julia development which comprises the following plants:—

Sils, on the Albula, in operation since 1908 but thoroughly reconstructed in 1944/45; two modern vertical-axle units, each driven by a 16,000 h.p. Francis turbine, have replaced the eight old sets, increasing production by about 35 M kWh, or 30 per cent.

Solis, on the left bank of the Albula just opposite its confluence with the Heidbach, now in course of reconstruction for automatic working with remote control from Sils; the two old generating sets are now being replaced by a modern unit consisting of a 10,000 h.p. Pelton turbine coupled to a 8,500 kVA generator.

Tiefencastel, also on the left bank of the Albula, just downstream of its confluence with the Julia; this, like Sils, is a run-of-river plant, which, however, draws part of its power water through a pressure tunnel from the 200,000 cu. m. compensation pool at Burvagn. This plant came into commission in 1949, and has two 16,000 h.p. sets producing yearly 140 M kWh, two-thirds of which during the summer.

Marmorea, in course of construction on the Julia; the powerhouse at Tinzen will house two units, each consisting of two 17,000 h.p. Pelton wheels driving a 26,000 kVA generator.

These four plants will have an aggregate installed capacity of 108,000 kW and a yearly production of 553 M kWh, of which 291 M will be generated between April 1 and September 30. Two additional projects are in course of preparation—Conters, on the Julia, with its tailrace flowing into the Burvagn pool, and Nandro, which is to draw its water supply from the Radons reservoir and will generate power in an extension of the Tinzen powerhouse. Once these two

plants are in operation, the Albula-Julia development will supply Zürich with 720 M kWh, of which about 51 per cent. will be available in summer. (H. Bertschi, *Wasser- & Energiewirtschaft*, Vol. 44, No. 5/7, 1952, p. 100, 4 pp., 3 ff.)

Note.—The above issue of *Wasser- & Energiewirtschaft* is entirely devoted to hydraulic development in the Grisons canton.

Controversy over Missouri Basin

Who will control Missouri Basin water? This long-simmering controversy moved a step closer to settlement last December, when Governors and other representatives of the ten states interested approved a compact under which states and Federal Government would be equal partners in the land and water development projects in the 529,000 sq. mile basin. Approval by the Congressional Committee involved and by the President's Office is expected. Rumblings, however, continue, and Oahe Dam is still under fire from two sides, an agricultural group wishing to substitute two smaller dams to eliminate the danger of land flooding, while another group, backed by private power companies, wants to suppress Oahe altogether. And yet another problem arises as to the ration of expenditures since, in the words of the Department of Agriculture representative, agricultural interests feel that the Missouri Basin programme has so far seriously neglected the watershed and upstream problems and improvements as compared with mainstream development. Against expenditures in the last seven years of 1.200 million dollars for controlling and using water in the river and its tributaries, no more than 200 to 250 millions have been spent for conservation resources before water reaches the rivers. (*Engineering News-Record*, Vol. 149, No. 24, Dec. 1952, p. 26, 2 pp., 2 ff.)

Pendulum Generators

The older mechanical transmissions used for driving turbine governors resulted in bulky and unsightly layouts, especially in the case of vertical sets, and electrical transmission is therefore generally favoured, a further advantage being that the speed ratio between the main shaft and the turbine pendulum can be chosen practically at will.

When the alternator has a direct-coupled auxiliary exciter this can be provided with sliprings connected to 120° tappings on the rotor winding to supply three-phase current to the pendulum motor. A special generator is thus avoided, the additional outlay on the exciter is moderate, and constructional height is saved. On the other hand this construction is suitable only for high-speed sets, and for low speeds a special generator is necessary. These generators require a very small pole pitch, and if they are to be of the electrically excited type it is impossible to consider a separate coil per pole. The Oerlikon Engineering Company have therefore adopted a claw-pole construction with a central magnetising coil.

The disadvantage of the electrically excited generator is that it does not excite—and therefore does not start the pendulum—until the main machine has reached 60—70 per cent. of full load. This can be overcome by using battery current for excitation during starting, but this introduces switching complications.

All these objections are overcome by the use of the permanent-magnet generator, but generators of this type have been rendered practicable only by the recent great advances in the production of magnet steel alloys. Such a generator gives a higher terminal voltage when running idle than when on load, and if this difference in voltage is not to be inadmissibly large the characteristic curve of the magnetic material must be such that the remanence is only slightly weakened by the demagnetising action of the machine when loaded. Cobalt steels are unsatisfactory in this respect, and it was only by the development of Al-Ni steels that a permanent-magnet generator of suitable characteristics became possible. Such generators are necessarily larger than those with exciter coils because the possible inductions are not so high, but even so, the cost is only about 2 per cent. of that of the main machine.

The article concludes with a brief account of tests on a pendulum governor driven by a permanent-magnet generator. (F. Seefeld, *Bulletin Oerlikon*, No. 291, October 1952, p. 7, 4 pp., 8 ff.)

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Appointments Vacant

The engagement of persons answering Situations Vacant advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18—64 inclusive or a woman aged 18—59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

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Further particulars and information as to the method of application should be obtained from the Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1.

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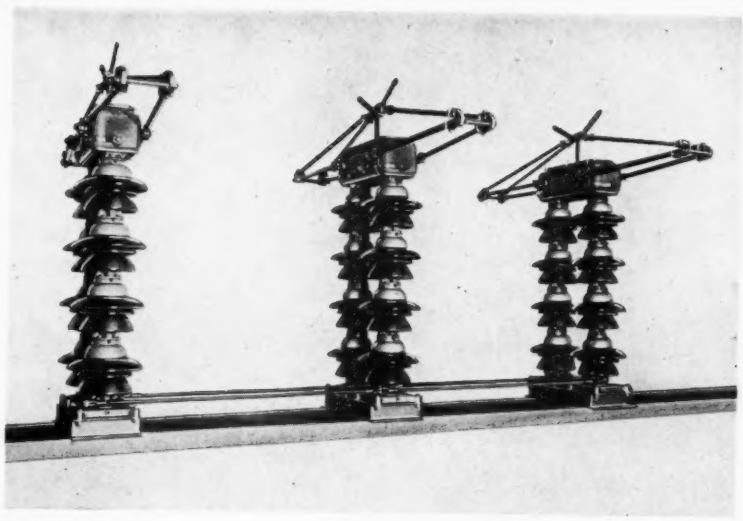

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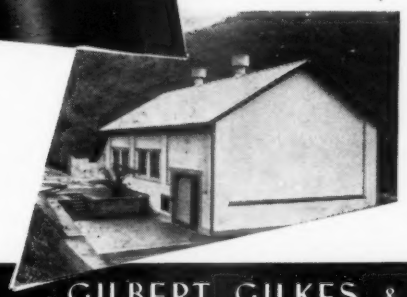

Above: Interior, showing the two 725 B.H.P. GILKES Francis Turbines

Right: Exterior of power station

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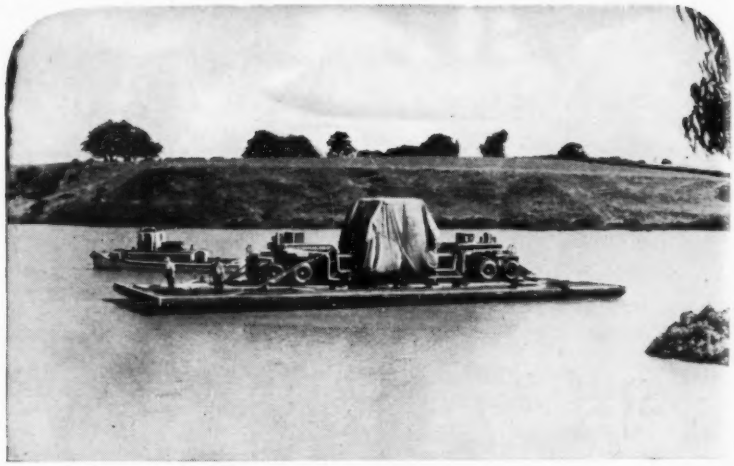

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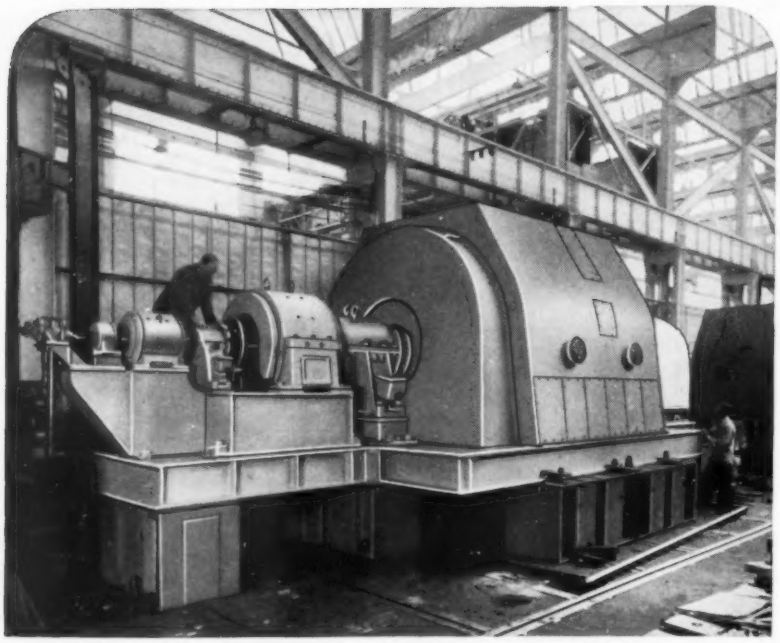

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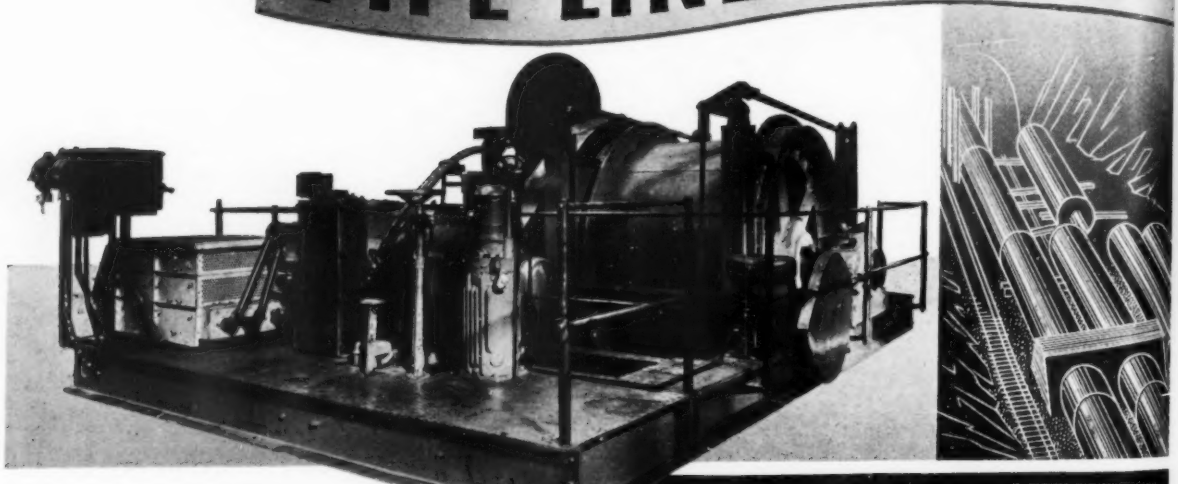

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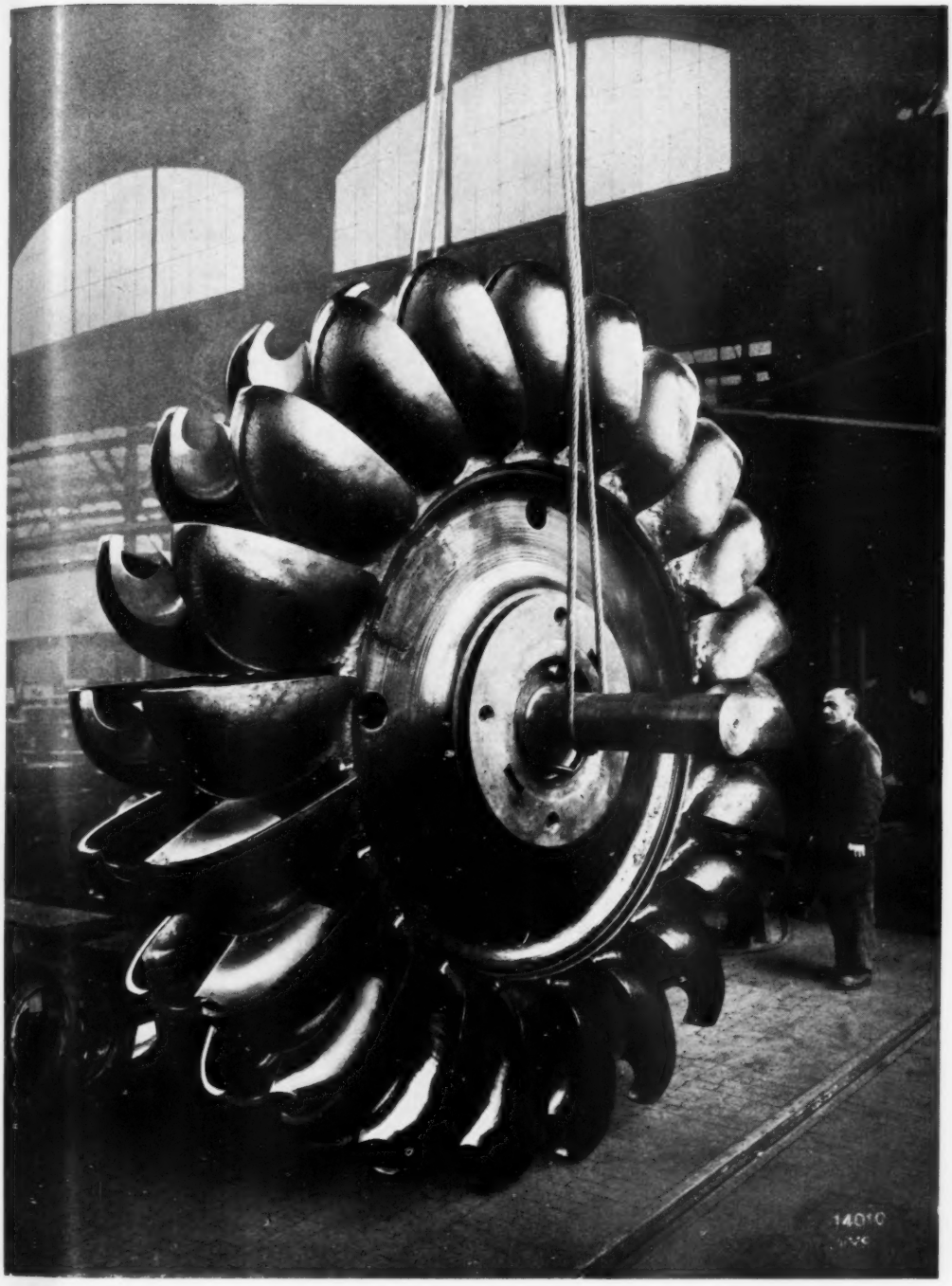

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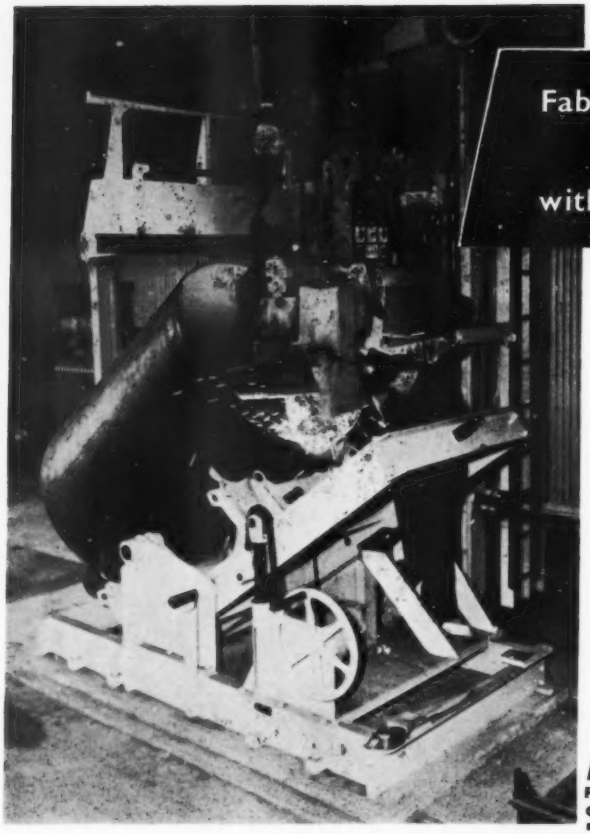

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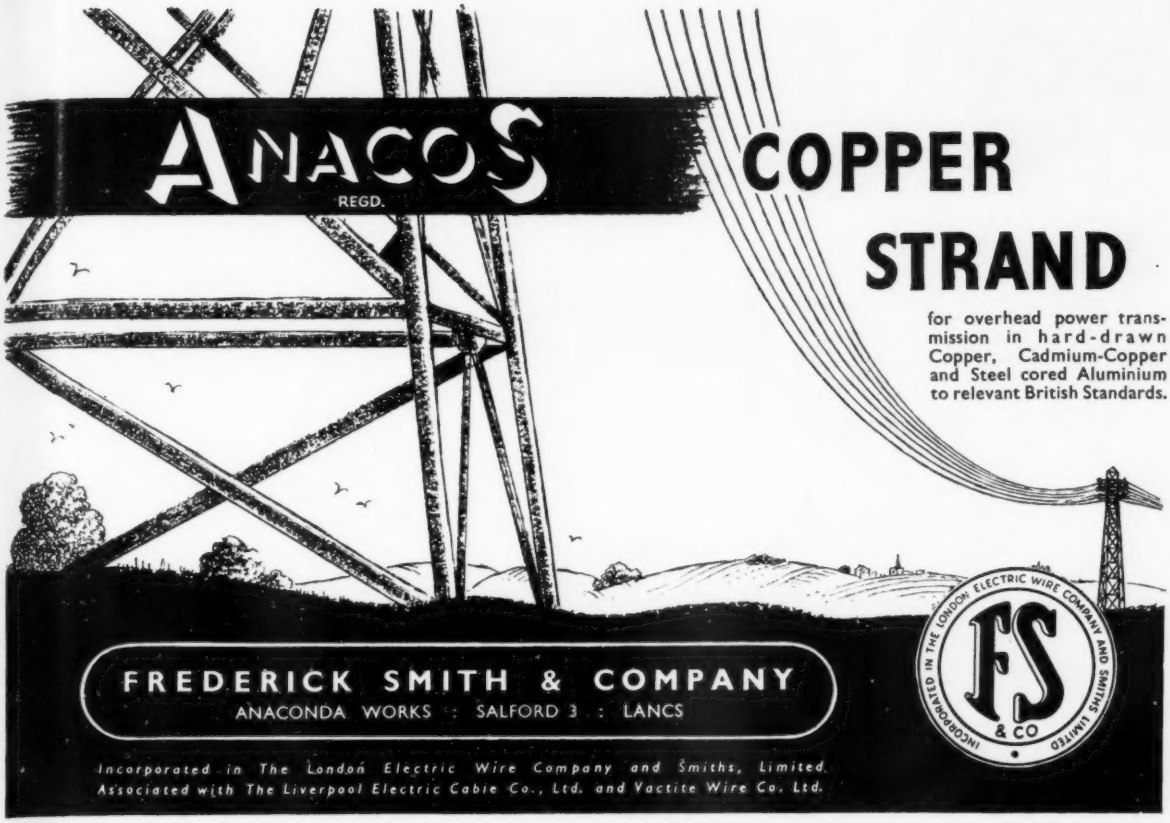
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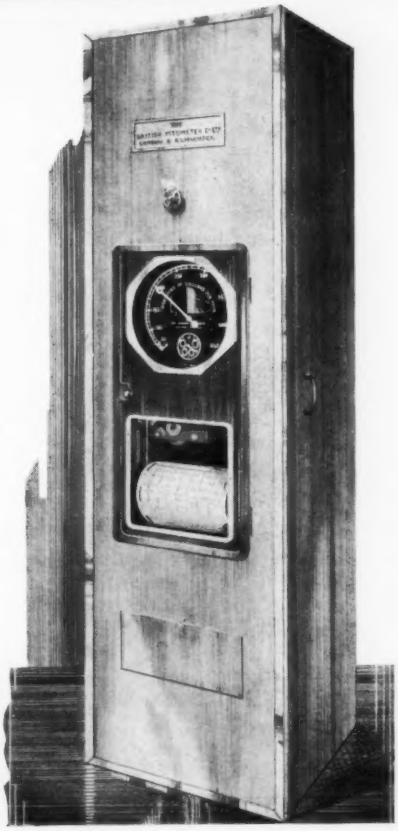

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INDEX TO ADVERTISEMENTS

A

Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitats Gesellschaft ... —
Allis-Chalmers 7
Allmanna Svenska Electriska Aktiebolaget ... 11
Aluminium Wire & Cable Co. Ltd. ... ... —
Anderson-Grice Co. Ltd. 46
Ansaldo, San Giorgio, S.p.A. ... ... —
Armfield Hydraulic Engineering Co. Ltd., The —
Arrol, Sir Wm. & Co. Ltd. 28
Ateliers de Constructions Electriques de Charleroi 19
Ateliers de Constructions Electriques de Delle —

B

Balfour, Beatty & Co. Ltd. ... ... —
Bayham Ltd. ... ... —
Bell, Theodore, Ltd. 38
Billington & Newton Ltd. 6
Birkett, T. M. & Sons Ltd. 6
Blackwood Hodge 45
Blakeborough, J. & Sons Ltd. ... ... —
Blaw Knox Ltd. ... ... —
Boving & Co. Ltd. ... ... *Front Cover*
Brady, G. & Co. Ltd. 17
British Insulated Callender's Cables Ltd. ... 42
British Pitometer, The, Co. Ltd. 49
British Ropeway Engineering Co. Ltd. ... —
British Thomson-Houston Co. Ltd. 44
Brown, Boveri & Co. Ltd. 29
Bruce Peebles & Co. Ltd. 4
Butters Bros. & Co. Ltd. 35

C

Canadian Vickers Ltd. ... ... —
Cementation Co. Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... —
Charmilles Engineering Works Ltd. 21
Consolidated Pneumatic Tool Co. Ltd. ... —
Costain, Richard, Ltd. 8

D

De Roll, Louis, Iron Works Ltd. ... ... —
Distington Engineering Co. Ltd. ... ... —
Dominion Engineering Co. Ltd. 27

E

English Electric Co. Ltd. 3
Escher Wyss Ltd. 47

F

Ferguson Pailin Ltd. ... ... —
Ferranti Ltd. ... ... —
Ferrum (England) Ltd. ... ... —
Fusarc Ltd. 48

G

Galileo Officine, di Battaglia Terme ... ... —
General Electric Company, International ... 24
General Electric Co. Ltd. 30
Gilbert Gilkes & Gordon Ltd. 43
Glenfield & Kennedy Ltd. ... ... —

H

Hackbridge & Hewittic Electric Co. Ltd. ... —
Harland Engineering Co. Ltd., The 40
Henderson, John M. & Co. Ltd. 12
Henley's W. T., Telegraph Works Co. Ltd. 36
Holman Bros. Ltd. ... *Inside Back Cover*

I

International Engineering Co., Inc. 5

K

Karlstads Mekaniska Werkstad 10

L

Leffel, James & Company, The 33

M

Marelli, Ercole & Co. ... ... —
Maschinenfabrik Augsburg-Nuernberg, A.G. —
Metropolitan-Vickers Electrical Co. Ltd. *Back Cover*
Michell Bearings Ltd. ... ... —

N

Newport News Shipbuilding & Dry Dock Co. 34
Nuttall Edmund Sons & Co. (London) Ltd. —
Nydqvist & Holm Akt. ... ... —

O

Olding, Jack (Onions) Ltd. 25
Oerlikon Engineering Company ... ... —

P

Painter Bros. Ltd. 15
Pegson Ltd. ... ... —
Pirelli-General Cable Works Ltd. 23

R

Ransomes & Rapier Ltd. ... ... —
Rawlplug Co. Ltd., The ... ... —
Reyrolle, A. & Co. Ltd. *Inside Front Cover*
Riva Costruzioni Meccaniche ... ... —

S

SACE Costruzioni Elettromecaniche ... 39
Salvi, A., & Company 18
Scarpa & Magnano 43
Smith, Fredk. & Co. 49
Smith, S. Morgan, Company 23
Smith, Thos. & Sons (Rodley) Ltd. 16
Societa Anonima Elettrificazione 14
Societa Condotte Forzate ... ... —
South Durham Steel & Iron Co. Ltd. ... —
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 32
Storey, Thos. (Engineers) Ltd. 20

T

Taylor, Tunnicliff & Co. Ltd. ... ... —
Tees Side Bridge & Engineering Works Ltd., The 46
Tosi Franco, S.p.A. 31

V

Vevey Engineering Works Ltd. ... ... —
Victor Products (Wallsend) Ltd. ... ... —
Voith, J. M., G.m.b.H. 13

W

Ward, Thos. W., Ltd. 26
Westinghouse Electric International Co. ... —
Wild, M. B. & Co. Ltd. 46
Wood, Hugh & Co. Ltd. 9
Woodward Govener Co. 37
Wykeham & Co. Ltd. ... ... —

Y

Yorkshire Electric Transformer Co. Ltd. ... —

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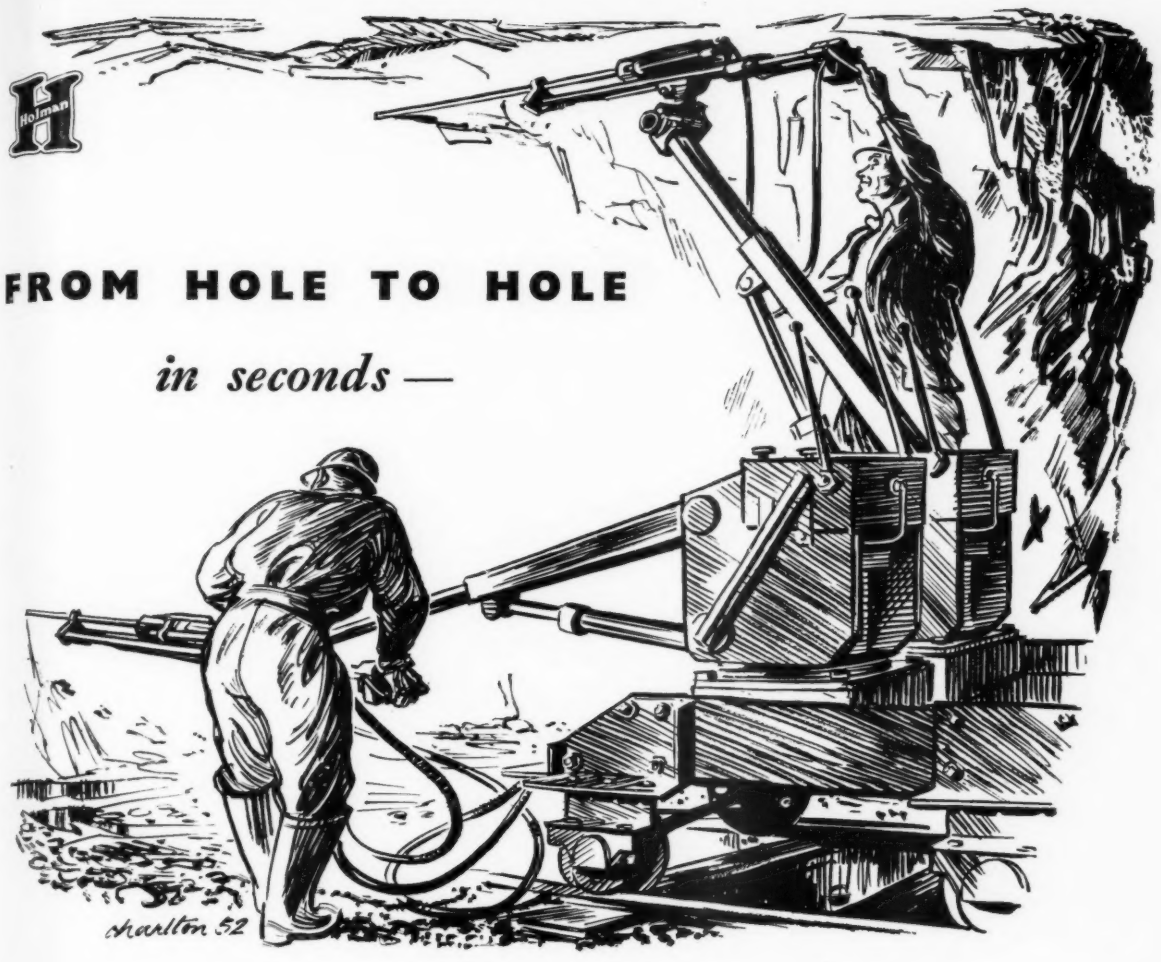

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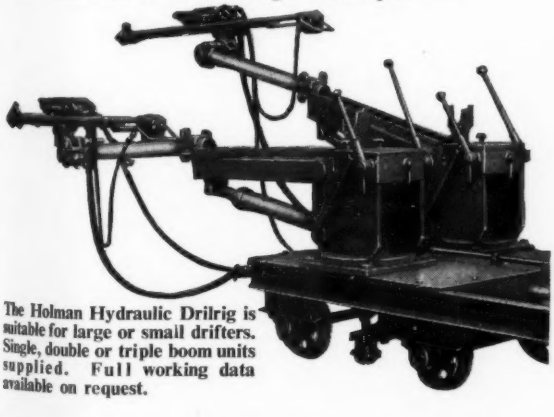

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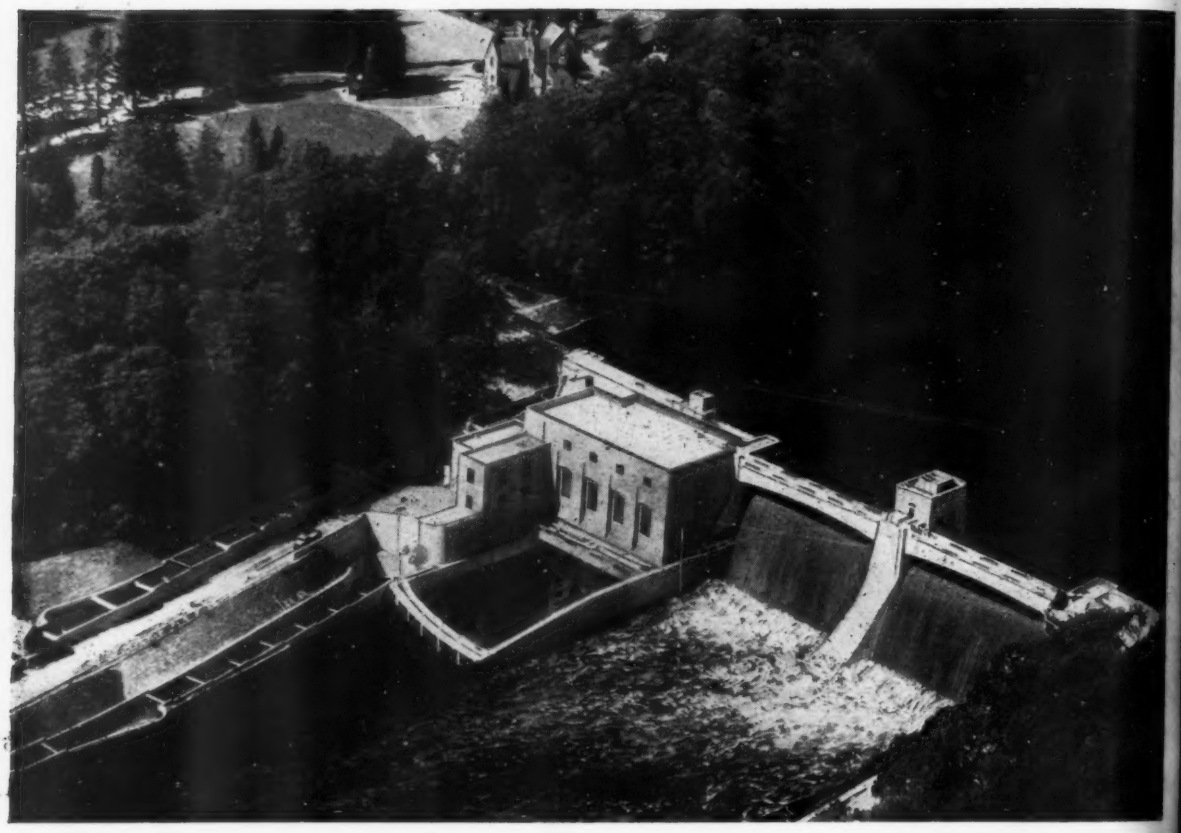

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